SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Digester Loading—Torpey

Flow Measurement—Brown and Symons

Evaluation of Odors—Beardsley and Krotinger

Coliform Data Analysis—Thomas

Lagoons for Metalworking Wastes—Griffith

Waste Pickle Liquor Disposal—Heise and Johnson

FEBRUARY, 1955—VOL. 27, No. 2

Make Plans to Attend

28TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

AMBASSADOR HOTEL
ATLANTIC CITY, NEW JERSEY

October 10-13, 1955

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

CATALYTIC REDUCTION PROCESS* Accelerates Sludge Digestion to Boost Tank Capacity

The CATALYTIC REDUCTION PROCESS is the only proved process for accelerating biological digestion. Originating in 1946, the PROCESS was developed, tested and verified over six years on both laboratory and plant scale. The results have been proven in full scale plant operation at the Columbus, Ohio and Erie, Pennsylvania Sewage Treatment Plants. The PROCESS is now being installed in four other cities.

DETAILS OF ONE TEST

The CATALYTIC REDUCTION PROCESS applied to one 70′ tank at the Columbus Plant digested 3.38 times the quantity of sludge solids digested in a similar tank in parallel operation not using the PROCESS. The tank operating under the PROCESS produced a reduction of solids within established ranges, normal gas production and readily driable odorless sludge.

PREVENTS FLOATING DIGESTIBLE SOLIDS

By providing accelerated digestion, the CATALYTIC REDUCTION PROCESS offers the only fundamental and satisfactory method for preventing deep surface accumulation (sometimes mistakenly called scum) of digestible solids that are symptomatic of inadequate digestion. CRP simultaneously accelerates and uniformly digests ALL digestible solids.

Reports Available

**Send for Examples. Reports describing the PROCESS in detail are also available on request. Write to Department H.*

**Patents Applied For*

CHICAGO PUMP COMPANY

Subsidiary of Food Machinery and Chemical Corporation

SEWAGE EQUIPMENT DEPARTMENT

111 DIVERSEY PARKWAY • CHICAGO 14, ILLINOIS

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

PRESIDENT

DAVID B. LEE
Director and Chief Engineer
Bureau of Sanitary Engineering
Florida State Board of Health

VICE–PRESIDENT

GEORGE W. MARTIN
Superintendent of Sewage Treatment
Green Bay, Wis.

TREASURER

W. W. DEBERARD
Deputy Commissioner for Water
Chicago, Illinois

EXECUTIVE SECRETARY–EDITOR

RALPH E. FUHRMAN
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. MOHLMAN
Director of Laboratories
The Sanitary District of Chicago
Chicago, Illinois

DIRECTORS

Alabama: J. L. CROCKETT, JR. (1957)
Arizona: LEIGH O. GARDNER (1955)
Arkansas: GLEN T. KELLOGG (1955)
California: F. G. NELSON (1956)
Canada: NICOL MACNICOL (1955)
Central States: M. L. ROBINS (1957)
Dakota: R. J. STAFF (1955)
Federal: L. B. DWORSKY (1956)
Florida: J. E. KIKER, JR. (1956)
Georgia: C. E. DRUMMOND (1956)
Germany: F. SIERP (1956)
Inst. San. Eng. (Eng.): W. F. BROWN (1956)
Inst. Sew. Pur. (Eng.): W. F. FREEBORN (1956)
Iowa: H. S. SMITH (1956)
Kansas: MYRON NELSON (1957)
Kentucky-Tennessee: F. W. KITTRELL (1955)
Louisiana: J. J. HOLTGREVE (1955)
Maryland-Delaware: ROY H. RITTER (1957)
Michigan: CLYDE L. PALMER (1955)
Missouri: J. K. SMITH (1957)
Montana: F. F. PALMER (1956)
Nebraska: T. A. FILIPI (1955)
New England: WILLIAM S. WISE (1957)
New Jersey: SOL SEID (1957)
New York: A. J. FISCHER (1957)
North Carolina: P. D. DAVIS (1955)
Ohio: G. A. HALL (1957)
Oklahoma: C. E. MOUTREY (1956)
Pacific Northwest: E. C. JENSEN (1956)
Pennsylvania: HOWARD T. REUNING (1955)
Puerto Rico: L. R. ROBLES (1956)
Rocky Mountain: B. V. HOWE (1957)
South Carolina: T. E. ROBERTSON, JR. (1955)
Sweden: NILS WESTBERG (1956)
Switzerland: PIERRE WILDI (1957)
Texas: C. H. CONNELL (1957).
Virginia: B. L. STROTHER (1956)
West Virginia: H. K. GIDLEY (1956)
At Large: KERWIN L. MICK (1955)
At Large: V. MACKENZIE (1956)
At Large: R. R. KENNEDY (1957)
W. and S. Wks. Mfgrs.: HARRY E. SCHLENZ (1955)
W. and S. Wks. Mfrgs.: W. A. HARDENBERGH (1956)
W. and S. Wks. Mfgrs.: G. W. KELSEY (1957)
Ex-Officio: L. J. FONTENELLI
Ex-Officio: M. M. COHN
Ex-Officio: SETH G. HESS
Ex-Officio: ROLF ELIASSEN
Ex-Officio: H. HEUKELEKIAN
Ex-Officio: W. J. ORCHARD
Ex-Officio: G. P. EDWARDS

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE
Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES
325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES
Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States $1.00 each; Foreign, $1.25 each.

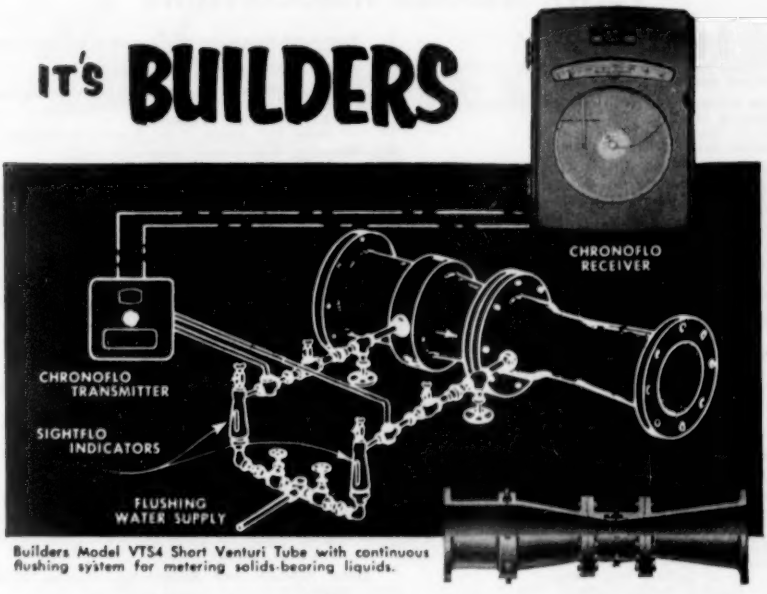
CLAIMS
No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

MAILING PERMIT
Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE
Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

IT'S BUILDERS



Builders Model VTS4 Short Venturi Tube with continuous flushing system for metering solids-bearing liquids.

...for the complete metering "package"

BUILDERS CHRONOFLO SYSTEM

for electrical transmission of flow information over any distance. Bulletin 230-K24.

BUILDERS VTS4 SHORT VENTURI TUBE

accurate, low loss of head, economical. Bulletin 110-K11.

BUILDERS CONTINUOUS FLUSHING SYSTEM

eliminates manual cleaning, improves metering efficiency. Bulletin 110-G1.

Builders offers a unique service to sewage and industrial waste treatment plants — *the complete line* of equipment for metering liquid flows . . . from the Venturi Tube in the pipe line to the Chronoflo metering instrument in the control panel. Find out about Builders metering "packages". For Bulletins, write Builders-Providence, Inc., 368 Harris Avenue, Providence 1, Rhode Island.

BUILDERS-PROVIDENCE

DIVISION OF B-I-F INDUSTRIES, INC.

BUILDERS IRON FOUNDRY • PROPORTIONEERS, INC. • OMEGA MACHINE CO.

BIF METERS FEEDERS CONTROLS

FSIWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
PROF. W. L. SAMUEL, *Secretary*
Alabama Polytechnic Institute
Auburn, Alabama

Arizona Sewage and Water Works Assn.*
QUENTIN M. MEES, *Sec-Treas.*
721 N. Olsen
Tucson, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
c/o Southern State College
Magnolia, Ark.

California Sewage and Industrial Wastes Assn.
J. C. MALLERY, *Sec.-Treas.*
4822 N. Dunsmore Ave.
La Crescenta, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Administrative Office
72 Greenville St.
Toronto, Ontario, Canada

Central States Sewage and Industrial Wastes Assn.
GEORGE F. BERNAUER, *Sec.-Treas.*
713 Chapman St.
Madison, Wis.

Dakota Water and Sewage Works Conf.

*North Dakota Section**
JEROME H. SVOBE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

*South Dakota Section**
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health, Pierre, S. Dak.

Federal Sewage Research Assn.
KEITH S. KRAUSE, *Sec.-Treas.*
Room 4212A South HEW Bldg.
Washington 25, D.C.

Florida Sewage and Industrial Wastes Assn.
M. E. DAWKINS, *Sec.-Treas.*
P. O. Box 210
Jacksonville 1, Fla.

Georgia Water and Sewage Assn.*
A. T. STOREY, *Sec.-Treas.*
1210 Hemphill Ave., N.W.
Atlanta, Ga.

(Germany) Abwassertechnische Vereinigung
OTTO FALLASCH, *Sec.-Treas.*
Theaterstrasse 24
Bonn, Germany

Institute of Sewage Purification
ARNOLD KERSHAW, *Sec.*
Sew. Purif. Dept.
Cippenham Lane
Slough, Bucks, England

Institution of Sanitary Engineers
ERNEST V. BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1, London, England

Iowa Sewage Works Assn.
L. F. SKORCZESKI, *Sec.-Treas.*
207 South 15th Ave.
Marshalltown, Iowa

Kansas Sewage and Industrial Wastes Assn.
ROBERT H. HESS, *Sec.-Treas.*
Supt. of Water and Sewage Treatment
City Building
Wichita 2, Kansas

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
S. LEARY JONES, *Sec.-Treas.*
420 Sixth Ave., N., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
GEORGE H. WEST, *Sec.-Treas.*
P. O. Box 15, Water Dept., Lake Charles, La.

* Sewage Works Section.

Maryland-Delaware Water and Sewerage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334, Admin. Bldg., Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg., Sixth Floor
Jefferson City, Mo.

Montana Sewage and Industrial Wastes Assn.
HARVEY W. TAYLOR, *Sec.-Treas.*
Morrison & Maierle Inc.
Helena, Montana

Nebraska Sewage and Industrial Wastes Assn.
V. J. LECHTENBERG, *Secretary-Treasurer*
614 Standard Oil Bldg., Omaha, Neb.

New England Sewage and Industrial Wastes Assn.
HENRY F. MUNROE, *Sec.-Treas.*
75 Pine Avenue, Cranston 10, R. I.

New Jersey Sewage and Industrial Wastes Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 766, Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C. SWEENEY, *Secretary*
c/o State Dept. of Health
21 N. Broadway, White Plans, N. Y.

North Carolina Sewage and Industrial Waste Assn.
W. E. LONG, JR., *Sec.-Treas.*
Box 2091, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
WARD E. CONRAD, *Sec.-Treas.*
301 Ohio Depts. Bldg., Columbus 15, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
JOHN P. SMOUSE, *Sec.-Treas.*
State Dept. of Health, Oklahoma City 5, Okla.

Pacific Northwest Sewage and Industrial Wastes Assn.
WALTER W. SAXTON, *Sec.-Treas.*
408 Old Capitol Bldg.
Olympia, Wash.

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ROBERT J. AULD, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832, San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
JOHN R. PETERSON, *Sec.-Treas.*
376 City and County Bldg., Denver, Colorado

South Carolina Water and Sewage Works Assn.*
T. A. KOLB, *Sec.-Treas.*
1329 Ellison Rd., Columbia, S. C.

(Sweden) Föreningen För Vattenhygien
ERIK JONSSON, *Secretary*
Box 5038, Stockholm 5, Sweden

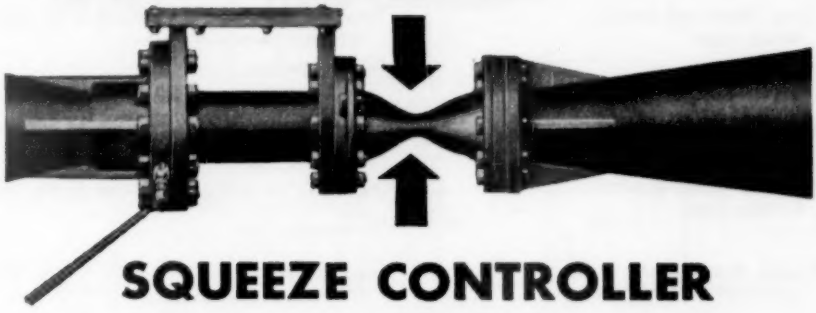
(Switzerland) Verband Schweizerischer Abwasserfachleute
EDUARD HOLINGER, *Treasurer*
Spitzackerstrasse 17, Liestal, Switzerland

Texas Water and Sewage Works Assn.*
V. M. EHLERS, *Sec.-Treas.*
2202 Indian Trail, Austin, Tex.

Virginia Industrial Wastes and Sewage Works Assn.
J. L. HAMRICK, JR., *Sec.-Treas.*
415 W. Franklin St., Richmond 20, Va.

West Virginia Sewage and Industrial Wastes Assn.
GLEN O. FORTNEY, *Sec.-Treas.*
State Dept. of Health, Charleston, W. Va.

New! **SIMPLEX**



SQUEEZE CONTROLLER

Accurately Controls Flow of Sewage, Sludge, Trade Wastes

For the first time, heavy viscous flows can be closely regulated without affecting the moving parts of the controlling device. This solves many problems . . . makes possible entirely new plant designs.

The core of this unit is a time-tested venturi tube with a special throat section of flexible rubber. Differential pressure in the venturi is transmitted to a Simplex Type H Rate Setter which both measures and maintains the flow desired. If flow tends to change, Type H Rate Setter actuates the motor-driven clamping device to adjust the flexible throat area . . . quickly returns flow to the control point.

Look at these advantages. A Simplex venturi tube, the most accurate form of primary device, does double duty, measures as it controls. The throat section is self-scouring. Viscous fluids contact no moving parts.

Write for complete details today!
Simplex Valve & Meter Company
Dept. S12, 7 E. Orange St., Lancaster, Pa.

SIMPLEX®
VALVE AND METER COMPANY

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Texas Water and Sewage Works Assn.	Texas A. and M. College, College Station, Texas	March 6–11, 1955
Louisiana Conf. on Water Supply and Sewerage	Louisiana State Univ., Baton Rouge, La.	March 16–18, 1955
Arkansas Water and Sewage Conf.	University of Arkansas, Fayetteville, Ark.	March 21–23, 1955
Kansas Sewage and Industrial Wastes Assn.	Baker Hotel, Hutchinson, Kan.	April 13–15, 1955
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	April 14–16, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955
Montana Sewage and Industrial Wastes Assn.	Finlen Hotel, Butte, Mont.	April 28, 1955
New York Sewage and Industrial Wastes Assn.	Hotel Ten Eyck, Albany, N. Y.	June 13–14, 1955
New England Sewage and Industrial Wastes Assn.	Hotel Ten Eyck, Albany, N. Y.	June 13–14, 1955
Ohio Sewage and Industrial Wastes Treatment Conf.	Deshler-Hilton Hotel Columbus, Ohio	June 22–24, 1955
Central States Sewage and Industrial Wastes Assn.	Kahler Hotel, Rochester, Minn.	June 22–24, 1955
Iowa Sewage Works Assn.	Hotel Waukonsa Fort Dodge, Iowa	Sept. 7–9, 1955
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Phoenix Hotel Lexington, Ky.	Sept. 12–14, 1955

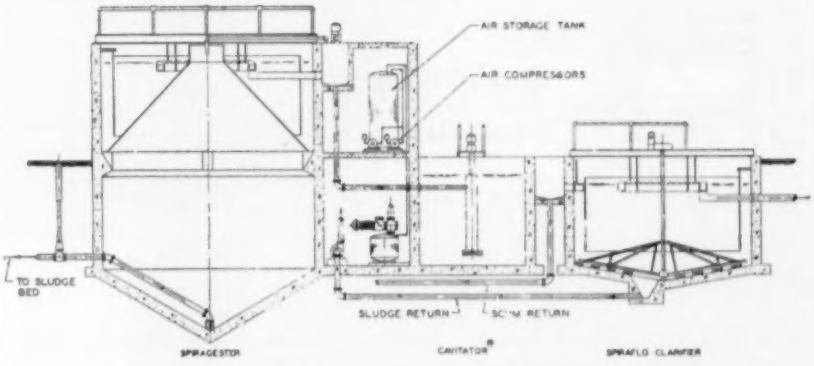
TWENTY-EIGHTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New Jersey Sewage and Industrial Wastes Association
Ambassador Hotel, Atlantic City, New Jersey
October 10–13, 1955

YEOMANS presents

THE CAVITATOR.* SYSTEM

for Municipal Waste Treatment



One of the many possible arrangements is illustrated. The secondary treatment is provided by the Cavitator mechanism, a specially designed rotor with two arms mounted on a hollow shaft through which air is drawn for dispersion through the tank contents. The arms are streamlined with the outer ends so constructed that when they are passed through the liquid at relatively high speeds they create a zone of cavitation through which the liquid is recirculated continuously. Air and liquid are drawn into the cavitation zone under vapor pressure conditions. As the bubbles rise they implode with such tremendous force that the pressure actually drives the oxygen into the tank.

—**high oxygen transfer efficiency**—requires only 135 cu. ft. of air per lb. B.O.D. removed per day in the Cavitator System.

—**exceptional performance on relatively low flows** with high B.O.D.

—**low installation and operating cost** with a high degree of purification.

Primary clarification and digestion is accomplished in a single structure, the Spiragester. A Spiraflo is used for final clarification.

Secure detailed information. See your local Yeomans representative listed in the Yellow Pages of your telephone book under "Pumps" or contact factory direct.

See following page for information on YEOMANS Spiragester

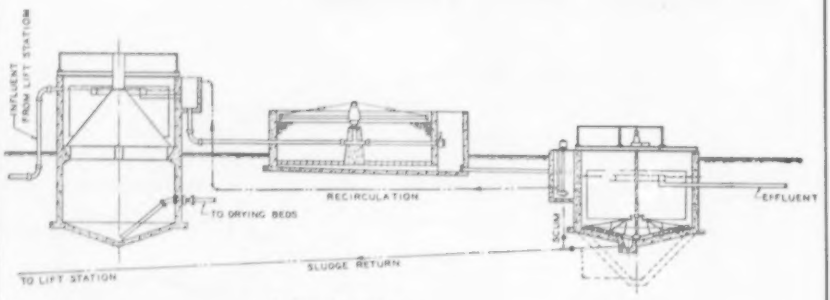
*A YEOMANS Tradename

YEOMANS BROTHERS COMPANY

1999-7 N. Ruby Street, Melrose Park, Illinois

Manufacturers of: Distributors · Clarifiers · Digesters · Mechanical Aerators
Pneumatic Sewage Ejectors · Centrifugal Pumps

YEOMANS
SPIRAGESTER



FLOW DIAGRAM

Combination clarifier and sludge digester—for primary and secondary treatment is securing results like these:—

45% Removal of B.O.D.—65% Removal of Suspended Solids—100% Removal of Settleable Solids.

Solids removal is accomplished in the upper portion of the Spiragester by spiral downward flow of the influent, introduced tangentially into an annular race, and enters clarification compartment at bottom. Diffusion is slow, uniform.

Settled solids in the clarification section enter the digestion compartment, mix actively with digesting material and are attacked by organisms which stabilize the sludge.

In the layout illustrated, secondary treatment is provided by a high capacity trickling filter and final sedimentation by a Spiraflo clarifier.

Ask for Typical Case History Performance Data. See your local Yeomans representative listed in the Yellow Pages of your telephone book under "Pumps," or write factory direct.

YEOMANS BROTHERS COMPANY

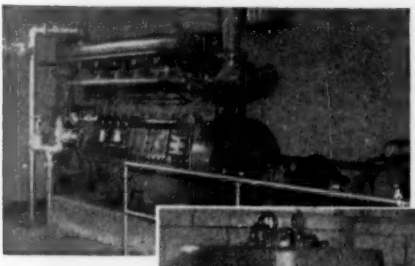
1999-7 N. Ruby Street, Melrose Park, Illinois

Manufacturers of: Distributors · Clarifiers · Digesters · Mechanical Aerators
Pneumatic Sewage Ejectors · Centrifugal Pumps

Long-wearing

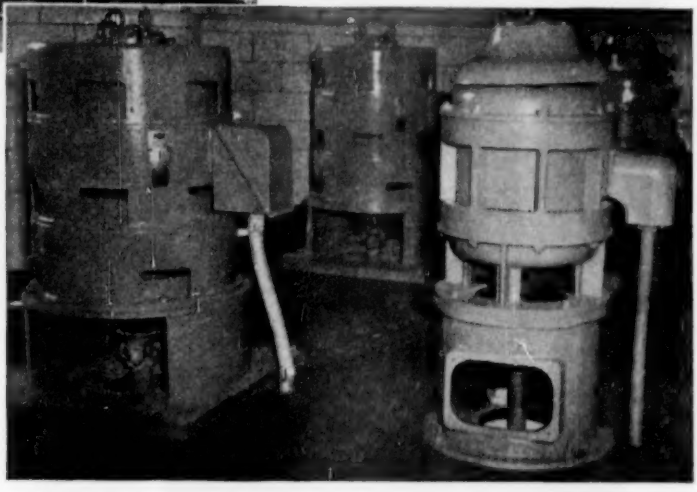
INERTOL® PAINTS

specified in Elmira, New York, plant



Sparkling protection was afforded this big gas engine at Elmira's Sewage Treatment Plant with Inertol Glamortex® Enamel. All surfaces were first primed with Inertol Quick-Drying Primer No. 626, a top-quality rust inhibitor which provides a perfect bond for the finish coats.

Easy maintenance of this battery of sludge pump motors was achieved with Glamortex Enamel, Battleship Grey No. 331. This easy-to-clean paint stands up for years under abrasion, oil spillage and frequent cleaning.



Inertol Paints meet precise requirement of plant designed by Nussbaumer, Clarke & Velzy

For top protection, Elmira's Sewage Treatment Plant needed paints that would provide lasting durability, elasticity and chemical resistance. That's why Inertol coatings were chosen for this modern plant which was designed and constructed under the supervision of Nussbaumer, Clarke & Velzy. Inertol meets all these exacting requirements. For 18 years, the city of Elmira has been using hundreds of gallons of Inertol Paints—bituminous coatings as well as colored enamels.

All over America, thousands of Inertol-painted installations speak for this paint's economical and efficient superiority. Whatever your specific painting problem is, there's sure to be an Inertol coating to solve it. Ask to have your local Inertol Field Technician call. Or write for our free "Painting Guide." It's prepared especially for Consulting Engineers, Specification Writers, Design Engineers and Plant Superintendents. Send for this valuable booklet today.

INERTOL CO., INC.

482 Frelinghuysen Ave.
Newark 5, N. J.

27H South Park
San Francisco 7, Calif.

THEY BOUGHT ON FAITH

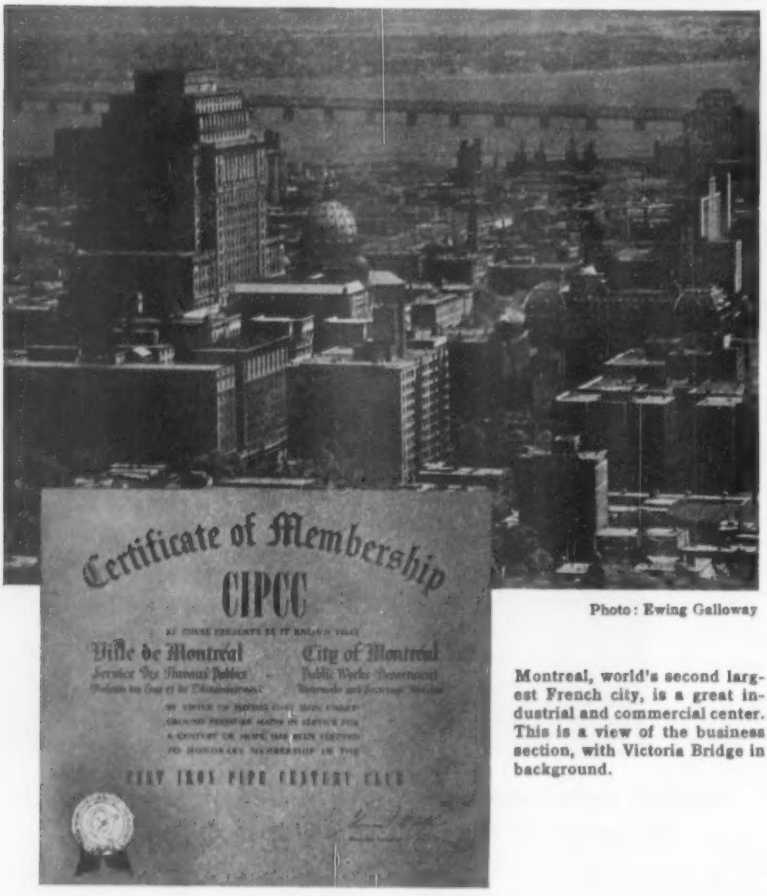


Photo: Ewing Galloway

Montreal, world's second largest French city, is a great industrial and commercial center. This is a view of the business section, with Victoria Bridge in background.

Montreal's Century Club certificate is unusual because it is bi-lingual.

MODERNIZED **cast iron**

139 YEARS AGO–THEY BUY ON PROOF TODAY

MONTREAL installed cast iron water mains 139 years ago . . . and still installs them.

The oldest existing cast iron water main on the North American continent is in Montreal, Canada's largest city. It was laid 139 years ago by the Company of Proprietors of the Montreal Water Works.* Several thousand feet of 2½" and 10" cast iron pipe laid in 1816 are rendering satisfactory service as part of Montreal's 1073 miles of mains, of which approximately 96% are cast iron.

*Now, Public Works Dept., WaterWorks & Sewerage Div.

This cast iron water main laid in Montreal in 1816 is still functioning after 139 years of continuous service.

Montreal's Public Works Department, and utilities in 60 other cities, bought and installed cast iron pipe for underground mains that have been in continuous service for more than a century. They bought on faith founded in good judgment. Today, they continue to buy cast iron pipe because they have *proof*—proof of the long life, dependability and tax-saving economy of this time-defying pipe.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

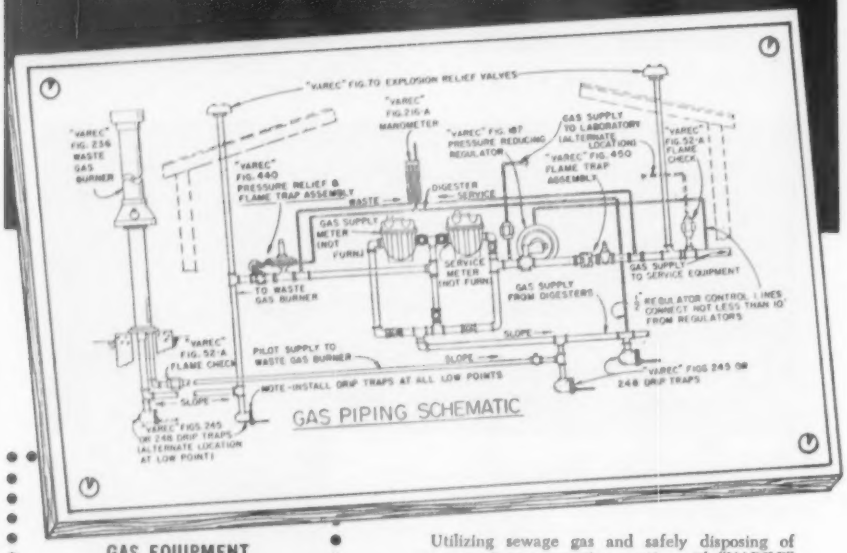
Cast Iron Pipe Research Association,
Thos. F. Wolfe, Managing Director,
122 So. Michigan Ave., Chicago 3.

CAST IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS OPERATION

"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. TO EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
DIGESTER — SERVICE
WASTE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
½" REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS 245 OR 248 DRIP TRAPS
"VAREC" FIGS 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINTS)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 440

FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 450

FLAME CHECK
"VAREC" Fig. No. 52A

EXPLOSION RELIEF VALVES
"VAREC" Fig. No. 70-1

WASTE GAS BURNER
"VAREC" Fig. No. 236

DRIP TRAPS
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

MANOMETERS
"VAREC" Fig. No. 216A

"Varec"

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

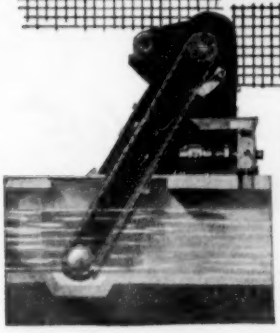
THE VAPOR RECOVERY SYSTEMS CO.
COMPTON, CALIFORNIA, U. S. A.
Cable Address: VAREC COMPTON USA (All Codes)

New York, N.Y. • Boston, Mass. • Pittsburgh, Pa. • Chicago, Ill. • Detroit, Mich. • St. Louis, Mo. • Houston, Texas • Tulsa, Okla. • San Francisco, Calif. • Seattle, Wash. • Minneapolis, Minn. • Honolulu, Hawaii

Available from authorized Sewage Equipment agents throughout United States and Canada

220 Cities Can't Be Wrong

REX FRONT CLEANED BAR SCREENS ARE BEST *because...*



Yes, 220 cities with over 300 installations offer proof of the leadership of Rex Front Cleaned Bar Screens. For over 20 years, Rex Screens have been satisfying customers throughout the United States and in many foreign cities. Here are some of the outstanding proven features of Rex Screens that make them leaders in their field.

1. **Streamlined Construction**—unobstructed flow to rack-guarded chain—streamlined sprockets.
2. **Rigidly Fastened Bar Rack**—bars accurately spaced—no obstructing cross members.
3. **Solid Plate Rake** with machined teeth for positive cleaning of bar rack and greater capacity.
4. **Positive Rake Wiping**—quiet—adjustable—prevents screenings carry-over to downstream side.
5. **Rex Z-Metal Chain** and attachments—corrosion and wear resisting.
6. **Split Head Sprockets**—easily removable.
7. **Efficient Drive Unit**—fully enclosed—shear pin protection against overload.
8. **Fully Enclosed Screen**—rugged design—neat appearance easy removal of screenings.
9. **Low Cost**—original operating—maintenance.

Your Rex Field Sales Engineer can give you the details on all of the advantages of Rex Front Cleaned Bar Screens. Call him today, or if you prefer, write to Chain Belt Company, 4606 West Greenfield Avenue, Milwaukee 1, Wisconsin.

CHAIN BELT REX COMPANY ®

Chain Belt COMPANY OF MILWAUKEE

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati Cleveland • Dallas • Denver • Detroit • El Paso • Houston • Indianapolis Jacksonville • Kansas City • Los Angeles • Louisville • Midland, Texas • Milwaukee Minneapolis • New York • Philadelphia • Pittsburgh • Portland, Ore. • West Springfield, Mass. • St. Louis • Salt Lake City • San Francisco • Seattle • Tulsa • Worcester

Distributors in principal cities in the United States and abroad

Export Offices: 4900 W. Mitchell St., Milwaukee; and 19 Rector St., New York City

PRINTED IN U. S. A.

how much does it cost...

to have *Safest*

CHLORINATION?

Nothing—when you buy a Fischer & Porter Chlorinator. That's true because fool-proof safety features are already engineered into this modern, instrument-type chlorinator.

The F&P Chlorinator is instrument engineered from top to bottom to be absolutely safe in any emergency—and the safety features respond instantly. The mechanical design—without hydraulic devices to introduce time lag—make this a certainty . . .

In the F&P Chlorinator you can take a hammer and shatter the flowmeter tube—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator you can pull the flow setting needle valve right out of its socket—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator you can shut off the ejector water supply while leaving the chlorine on—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator a simple series of hand manipulations tests each safety component—or shows the reason for malfunctioning should it ever occur.

These safety advantages are yours in the Fischer & Porter Chlorinator. They cost you not one penny more at the outset, since the F&P Chlorinator is lower in first cost. They avoid constant costs of repeated safety tests and checks. They assure you against high costs of repairs and maintenance. We don't put our safety devices under a bell jar—they are right out in the open where you can see and touch them.

These engineered features—*instrument-type engineering*—make the F&P Chlorinator the safest ever built. And you get all these safety features *plus* ease of operation, dependability proven in over 600 operating units, complete corrosion resistance—everything you should have in a chlorinator—and you get them for even less cost in the initial purchase. Write today for full information, details on free trial offer, and *absolute guarantee of satisfaction.*

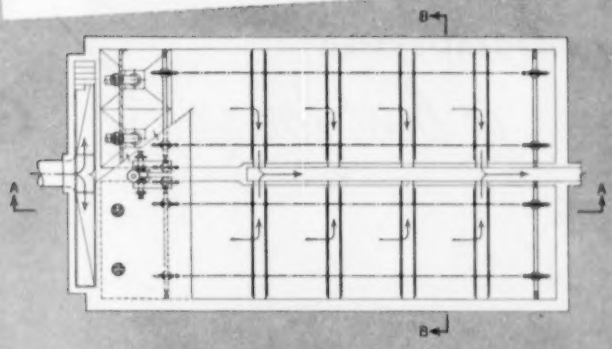
complete process instrumentation

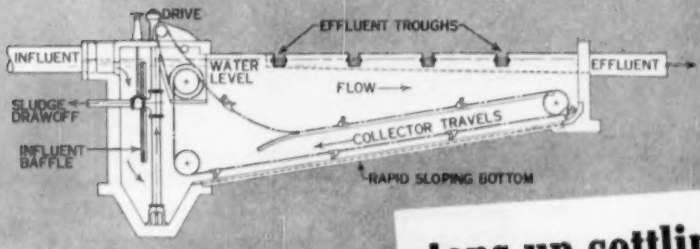
FP FISCHER & PORTER CO.

1125 Fischer Road, Hatboro, Penna.

18 YEARS SUCCESSFULLY MANUFACTURING CHLORINE CONTROL EQUIPMENT

New UNIFLOW settling tank





Link-Belt's new UNIFLOW settling tank can be utilized for economical removal of solids from water, sewage or industrial liquids. Uniflow tanks are equipped with Link-Belt Straight-line Sludge Collectors which will remove sludge from the tank floor and scum from the surface.

steps up settling efficiencies . . cuts construction costs

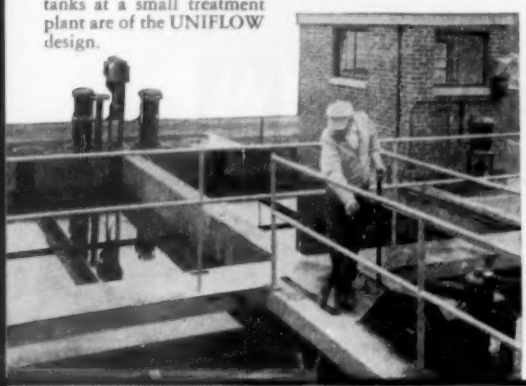
LINK-BELT development offers new economies for water, sewage and industrial liquids treatment

WITH its rapidly sloping bottom and multiple effluent weirs, Link-Belt's new UNIFLOW settling tank represents a big design advance. These, combined with the decreasing cross sectional area, provide *uniform velocity throughout the tank.*

Result: Better settling conditions . . . low overflow rate . . . uniform discharge from a large area of the tank surface. In fact, on one New England experimental installation, UNIFLOW gave practically the same efficiency in B.O.D. and suspended solids removal as a conventional tank with one-third more volume.

The new economies possible with UNIFLOW are typical of the development work constantly under way at Link-Belt. If you have a water, sewage or industrial waste problem, our engineers will work with your engineers, chemists and consultants. They'll help you get the finest in modern treatment equipment.

Primary and final settling tanks at a small treatment plant are of the UNIFLOW design.

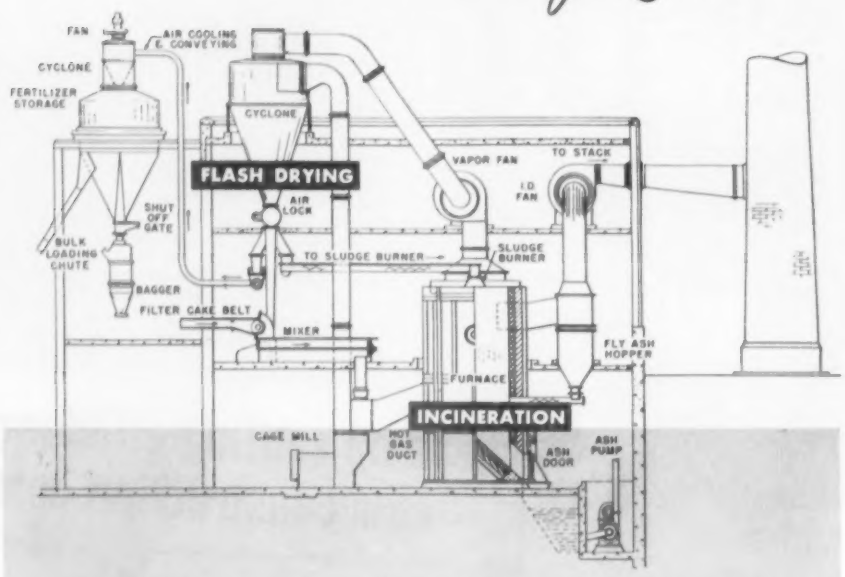


LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.403

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

Which **SLUDGE DISPOSAL SYSTEM** *is best for you?*



Only the C-E Raymond System of Flash Drying & Incineration offers the proved, practical flexibility which permits *either* flash drying sewage sludge to a marketable fertilizer . . . or incinerating it to a sterile ash—in any proportion and under complete control. In either case, too, high temperature deodorization of stack gases may be included if you wish.

This flexibility of the C-E Raymond System is an important reason why it is the most widely used heat method of sewage sludge disposal. In fact, the total daily capacity of C-E Raymond Systems installed, under construction or on order is *nearly 50% more than all other heat methods combined.*

Furthermore, the C-E Raymond System has been proved in service in communities of every size—ranging in equivalent population from 6,000 to 3,600,000—and located in every section of the country, coast to coast.

So, whatever your particular requirements, look to the leader for help in selecting the proper equipment. The services of a qualified engineer are freely available to you or your consultants. B-755A

COMBUSTION ENGINEERING

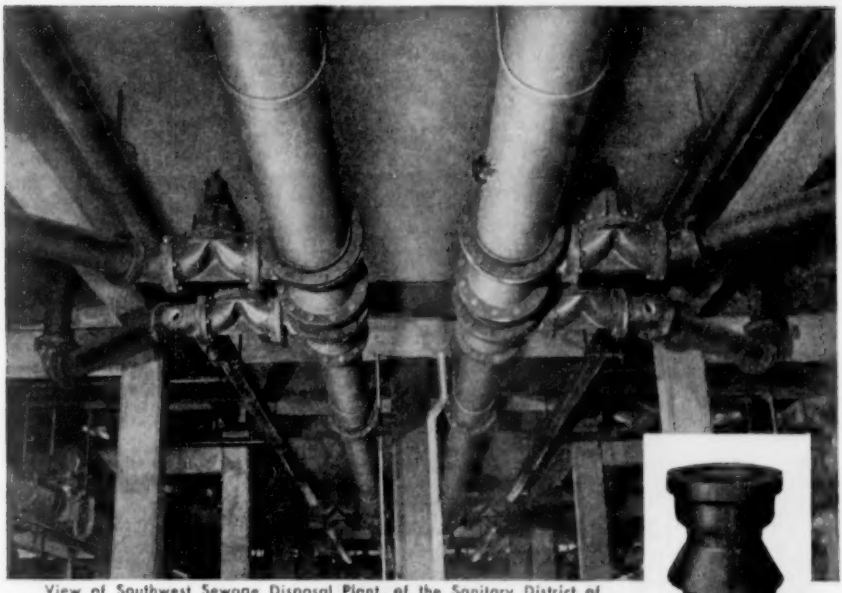
C-E

RAYMOND DIVISION

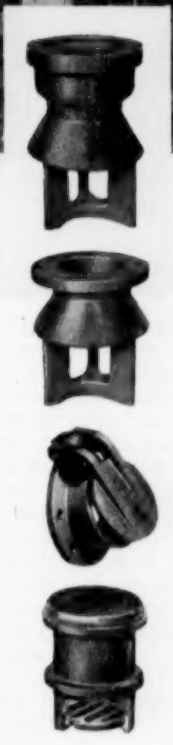
1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y. Western Office: 510 W. Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.



Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

JAMES B. CLOW & SONS ☆

201-299 North Talman Avenue • Chicago 80, Illinois

Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

A School? No!

*This plant was designed by Henry W. Taylor, Freeport, N. Y.

It's an

INCINERATION PLANT

serving Hempstead, N. Y.

- Large but not an eye-sore
- Efficient and flexible

Serving some 450,000 people, this plant provides an excellent example of the way larger communities are handling their refuse problems. Land-filling can no longer be tolerated in the suburban areas and should not be tolerated *anywhere*. Yet, there's no need to have an incinerator plant that's offensive to the nose and eye. Modern design and modern operation take care of the nuisance factors.

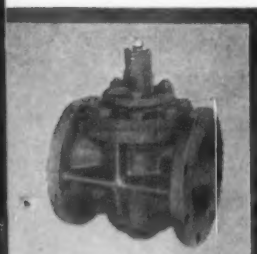
For this Hempstead plant, we furnished four Morse Boulger Mechanically Stoked Furnaces for handling up to 700 tons of refuse per 24 hours. Waste heat boilers recover much of the heat and provide steam for two 1000 kw. turbo-generators. Our engineers also furnished the crane charging equipment, stacks, fly ash removal unit and ash removal conveyor.

What we did to help in this Hempstead project we can do to help you...working with your sanitation engineer or your consulting engineer. The point to keep in mind is that your community, too, can have clean, efficient, nuisance-free refuse disposal in a modern incineration plant such as this Morse Boulger plant.

MORSE BOULGER DESTRUCTOR CO.

205-D EAST 42nd STREET • NEW YORK 17, N. Y.

Get All The Facts . . .



Rockwell-Nordstrom wrench operated valve

Rockwell-Nordstrom gear operated valve

Rockwell No. 120 pressure regulator

Rockwell No. 800 aluminum case large capacity sewage gas meter

Rockwell No. 5 pressed steel case large capacity sewage gas meter

FREE

How Rockwell-Nordstrom Valves Cut Costly Trouble on any sewage and waste treatment service . . .

If you've ever had the problem of stuck, leaking or unreliable valves, the story of Rockwell-Nordstrom valves will make sense to you—and save dollars. A *new* 20 page book shows you *all* the ways Rockwell-Nordstrom valves—and other Rockwell products—can help in your sewage or waste treatment plant. It's yours for the asking.

The *tapered plug* principle of Rockwell-Nordstrom valves, plus the many advantages of pressurized lubrication, have proven through the years that ordinary valves can't compare with Nordstrom's leak proof dependability and trouble-free operation. But that's just part of the story. You'll be interested, too, in the complete line of operating accessories such as chain wheels and water tight gear housings and many others that make Rockwell-Nordstrom the most versatile valve you've ever used. The new book also points out the numerous advantages of Rockwell regulators and sewage gas meters that are designed especially for your services.

We'll be glad to send you a complimentary copy of this valuable new book, Rockwell Products for Sewage and Waste Service. Just send the coupon below.

Canadian Valve Licensee: Peacock Brothers Limited

ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF

Rockwell Manufacturing Company
Pittsburgh 8, Pennsylvania

7-B

☐ Please send me Bulletin C-6200.
☐ Please have your sales engineer call.

Name _____ Title _____

Address _____

City _____ Zone _____ State _____

At Enid, Oklahoma . . .

A plant is rebuilt for expandable treatment

WITH MODERN PFT EQUIPMENT

A population growth of nearly 30% in the last 10 years (now 36,000), rendered Enid's 1928 sewage treatment plant obsolete. City leaders looked far ahead in approving plans for a vastly improved system—a plant designed to permit *doubling* its capacity with a minimum of cost and effort!

Assisting the engineers in meeting specific plant requirements, PFT supplied the following equipment for modern "controlled digestion."

Two *PFT Floating Covers* for the 70' digesters. The covers provide positive scum submergence for accelerated digestion and to safely utilize gas produced in the digester.

Two *PFT Cover Position Indicators* with low level alarms to allow checking of the liquid level in each digester from the operating floor of the control building.

Two *PFT Supernatant Selectors* (with Gauge, Sight Glass and Sampler units) for continuous withdrawal of the best digester liquor.

A *PFT Heater and Heat Exchanger* (750,000 B.T.U. per hr.) to keep digesters at optimum temperatures. Fired by sludge gas or natural gas, the unit saves fuel costs by utilizing all sludge gas produced, changing to natural gas only when necessary.

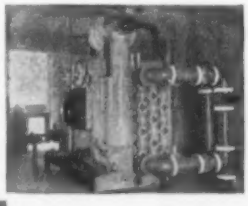
A *PFT Gravity Displacement Type Low Pressure Gas Holder* for compressor control.

In addition, PFT supplied many items of gas safety equipment: *Waste Gas Burner; Flame Traps; Pressure Relief with Waste Gas Flame Trap; Auxiliary Flame Cells; Accumulators; Drip Taps; Gas Pressure Gauge; Low Pressure Gas Check Valves.*

PFT assures the successful operation of its equipment by checking each installation and instructing plant operators in the proper methods of using its equipment.

Design of plant by / *Hudgins, Thompson & Ball Associates, Oklahoma City, Architect—Engineer; Bernal H. Swab, Sanitary Engineer.*

PFT Heater and heat exchanger unit



P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

4241 Ravenswood Avenue
Chicago 13, Illinois

PORT CHESTER, N. Y. • SAN MATEO, CALIF. • CHARLESTON, N. C. • JACKSONVILLE • DENVER

Rockwell No. 5 pressed steel case
large capacity sewage gas meter
City Zone State

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 February, 1955 Number 2

Contents

Sewage Works

Loading to Failure of a Pilot High-Rate Digester. By Wilbur N. Torpey 121
Discussion by Harry E. Schlenz 133
Discussion by H. Heukelekian 142
Discussion by Henry R. King 145
Flow Measurement in Sewage Works. I. Fundamentals. By Walter H. Brown and George E. Symons 149
Evaluation of Odors. By C. W. Beardsley and N. J. Krotinger 157
Effect of Dried Sewage Sludge on Nitrification in Soil. By James E. Fuller and G. W. Jourdian 161
Effect of Bacterial Flora on Deoxygenation. By William L. Tidwell and J. H. Sorrels 166
Housefly Breeding in Sewage Sludge. By Harold W. Wolf 172
Scientific Basis for Liming of Digesters—A Discussion. By Peter J. Neubpiel and Philip F. Morgan 177

Industrial Wastes

Lagoons for Treating Metalworking Wastes. By Charles R. Griffith 180
Disposal of Waste Pickle Liquor by Controlled Oxidation and Continuous Lime Treatment. By Lorenz W. Heise and Milton Johnson 190
Discussion by Richard D. Hoak 196
Treatment Machine Shop Wastes Containing Emulsified Oils. By C. W. Hathaway 198
Discussion by T. R. Haseltine 203
Operation of Ion Exchange Units for Treatment of Electroplating Wastes. By T. J. Fadgen 206
Dissolved Air Recovery of Suspended Solids. By Joseph Osterman 209

Stream Pollution

Statistical Analysis of Coliform Data. By Harold A. Thomas, Jr. 212

The Operator's Corner

Operator Status 223
Basic Elements of Digester Operation. By William R. Copeland 224
Florida Operator's Association Honors T V Star 227
The Daily Log, Aurora, Ill. By Walter A. Sperry 228
California Safety Committee 231
Screw Conveyor for Digester Grit Removal. By Andrew Palmer 232
Interesting Extracts from Operation Reports: Waterbury, Conn.; AEC Laboratory Waste Treatment Facility, Los Alamos, N. Mex. 233
Stockholm, Sweden, Plan for Locating Sewers 238
Tips and Quips 238

Reviews and Abstracts 241

Proceedings of Member Associations

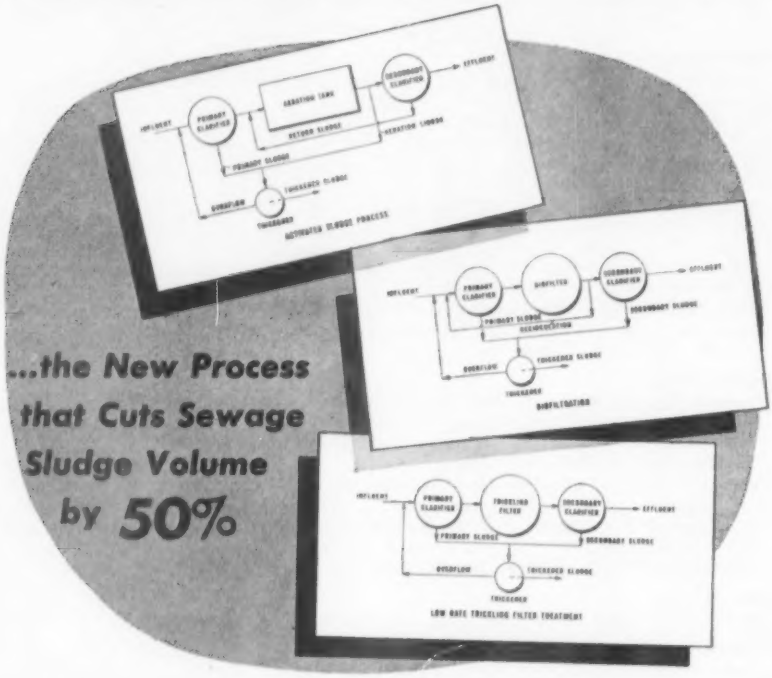
Georgia Water and Sewage Association 64a
Pacific Northwest Sewage and Industrial Wastes Association 64a

Equipment and Supply Lines 68a

Ralph E. Fuhrman, *Editor*, 325 Illinois Building, Champaign, Illinois
Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*
Donald P. Schiesswohl, *Assistant Editor* Mrs. A. H. Skates, *Editorial Assistant*

Copyright, 1955, by the Federation of Sewage and Industrial Wastes Associations. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

DENSLUDGE...



The Dorrco Densludge Process is a new means of producing a thicker sewage sludge in both primary and secondary treatment plants. It reduces sludge volume by as much as 50%—substantially simplifying digestion and disposal problems.

More specifically, these greatly reduced sludge volumes mean proportionately smaller digesters in new plants and increased digester capacity in existing plants. They mean lower initial costs for digesters in new construction and plant expansion alike. And Densludge eliminates digester supernatant, reduces digester heat requirements and improves suspended solids removal in the primary clarifier as well.

Bulletin #6260 describes how the process works, gives average operating results on three types of sewage sludge and covers the Dorr Densludge Thickener — the equipment key to the process. We'd like to send you a copy — without obligation, of course.

Write to Dorr-Oliver Inc., Stamford, Connecticut, or in Canada, 26 St. Clair Avenue East, Toronto 5.

DORR-OLIVER
INCORPORATED
WORLD WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

Sewage Works

LOADING TO FAILURE OF A PILOT HIGH-RATE DIGESTER *

By Wilbur N. Torpey

Engineer of Treatment, Bureau of Sewage Disposal Operation, Department of Public Works, New York City, N. Y.

In a previous paper (1) the writer has described the full plant-scale digestion of thickened combined primary and activated sludge at the Bowery Bay sewage treatment plant in New York City. Raw sludge volume was reduced by a combined thickening process to the same quantity as was formerly produced after digestion in an adequate conventional two-stage system. The plant sludge was satisfactorily digested in a tank providing 0.5 cu. ft. per capita. Further increases in loading rates could not be attained in this full-scale operation, since the entire solids capture of the plant was being applied to the irreducible minimum of one digester. It became apparent that in order to investigate higher loading rates, a pilot-plant installation would be required.

The operation of such a pilot would afford the opportunity to study sludge digestion under gradual increases of load until the process failed. The performance of the plant digester could be compared with that of a similarly loaded pilot unit whose operating volume would be effectively utilized by positive mixing of its contents.

Description of Pilot Digestion System

A pilot digestion system was therefore installed and placed in operation at the Bowery Bay plant. A schematic diagram of this equipment is shown in Figure 1.

Thickened combined primary and activated sludge (2) was fed to the pilot high-rate digester. It consisted of a 21-in. diameter, 36-in. high steel tank equipped with a mechanical stirrer and internal hot-water coils. The digesting sludge volume was maintained at 6 cu. ft.

Sludge was displaced to the "residual gas extractor" for converting the remaining gasifiable material escaping the high-rate digester. For the first part of the run the residual gas extractor was an unheated unstirred steel drum having a sludge volume essentially equal to that of the high-rate unit. For the last quarter of the investigation, this tank was replaced by a heated stirred tank of the same dimensions as the digester and is the unit shown in Figure 1.

Sludge from the extractor overflowed into a sludge receiver through an adjustable hose. The setting of this hose controlled the level of sludge in the tanks. Connections were provided for sampling the sludge leaving both the high-rate digester and the residual gas extractor.

Gas generated in each unit was measured by individual wet-test meters. Sampling cocks were provided on each gas line. Condensate was removed by means of a trap in the gas line.

Hot water from a thermostatically controlled reservoir was pumped through the heating coils of the tanks. The volume of the circulated heating

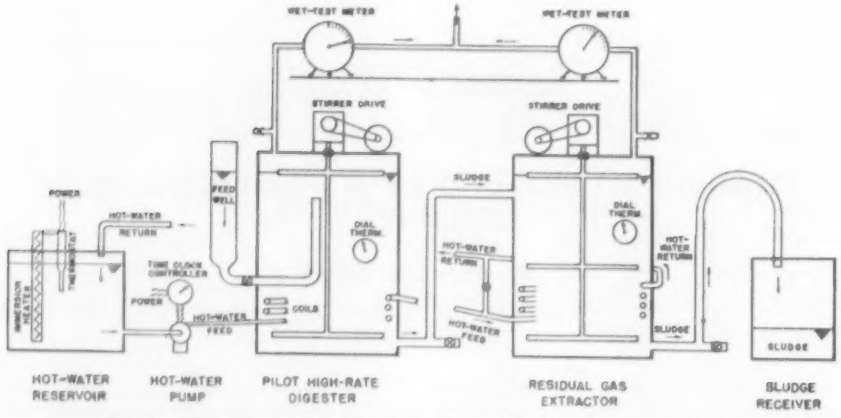


FIGURE 1.—Schematic diagram of pilot high-rate digester equipment.

water was controlled by means of an adjustable time clock on the power supply to the pump so as to maintain a digester temperature between 90° and 100° F. These temperatures were measured by dial thermometers inserted into wells in each tank.

Experimental Routine

Much consideration was given to the selection of a method of adding raw sludge to the digester to provide a high frequency of feeding. Such a method would necessarily have to be practical and reliable. It was decided that manual feeding by the plant operating force would afford an effective means of satisfying these considerations.

Each day a large sample of the thickened combined primary and activated sludge was obtained from the thickening tanks, divided into 12 equal portions, and stored under refrigeration. These were manually poured into the feed well at 2-hr. intervals, seven days a week, without interruption, for more than seven months.

The daily routine included checking the heating and stirring equipment, recording temperature and gas production data, measuring the volume of displaced sludge in the sludge receiver, and collecting samples for analysis.

These samples included a representative portion of the raw sludge feed, a grab sample of the sludge leaving the high-rate digester, and a portion of the sludge in the sludge receiver. Every morning these samples were analyzed for total solids, volatile matter, pH, liquor alkalinity, and volatile acids. The volatile acids and the pH determinations on the sludge leaving the residual gas extractor were performed on a grab sample to avoid changes on standing. All volatile acids determinations relative to the pilot plant were performed in accordance with the procedure outlined in "Standard Methods" (3) using a Kjeldahl distillation flask with rubber stopper to prevent leakage. The alkalinity concentration was measured potentiometrically on liquor centrifuged from the sludges. The pH was determined potentiometrically on the grab sludge samples.

Plan of Experiment

It was intended to start the pilot digestion system under the same operating conditions as those prevailing in the plant. The pilot high-rate and the residual gas extractor units would be filled with sludges from the corresponding plant digesters and pilot temperatures adjusted to the same range as those in the larger units. The pilot

TABLE I.—Loading of Digester with Thickened Combined Primary and Activated Sludge

Period No.	Dates (1953–4)	Days	Raw Sludge							Loading Rate				Dig. Temp. (° F.)
			Feed (cu. ft./day)	Displ. Period (days)	Dry Solids (%)		Vol. Acids (p.p.m.)	pH	Liquor Alk. (p.p.m.)	Dry Solids (lb./day)		Unit Loading (lb./day/cu. ft.)		
					Total	Vol.				Total	Vol.	Total	Vol.	
1	6/17–30	14	0.43	14.0	5.8	74.9	2,000	5.6	1,090	1.6	1.2	0.27	0.20	93
2	7/1–30	30	0.58	10.3	4.5	73.3	1,600	5.6	870	1.7	1.2	0.28	0.20	89
3	7/31–8/14	15	0.72	8.3	4.8	67.7	2,100	5.6	1,110	2.2	1.5	0.37	0.25	90
4	8/15–9/23	40	0.94	6.4	4.5	71.3	1,500	5.6	770	2.7	1.9	0.45	0.32	92
5	9/24–10/18	25	1.28	4.7	4.2	73.6	1,400	5.7	690	3.4	2.5	0.57	0.42	92
6	10/19–11/22	35	1.63	3.7	4.5	73.7	1,600	5.7	810	4.7	3.5	0.78	0.58	95
7	11/23–12/17	25	1.86	3.2	5.8	75.2	1,600	5.7	920	6.9	5.2	1.15	0.87	97
8	12/18–12/22	5	2.04	2.9	5.7	78.0	2,200	5.7	1,150	7.4	5.8	1.24	0.97	96
9	12/23–12/27	5	2.28	2.6	6.2	78.2	2,100	5.7	1,130	9.0	7.1	1.51	1.18	98
10	12/28–1/1	5	2.28	2.6	5.8	80.9	2,200	5.7	1,150	8.5	6.9	1.42	1.15	101
11	1/2–1/26	25	0.42	14.3	6.3	80.0	1,900	5.7	1,040	1.7	1.4	0.28	0.23	101
Plant	6/17–1/26	224	13,600	13.3	5.1	74.5	1,700	5.7	900	44,400	33,100	0.25	0.18	90

installation would initially be operated at a feed rate matching the nominal displacement period of the plant digesters. When a satisfactory biochemical equilibrium was established in the pilot tank, a program of increasing the feeding rates would be started. Thus, after operating at a given rate for sufficient displacement periods to demonstrate stability at that feed level, the load would be progressively increased until, eventually, a loading rate would be reached at which failure of the digestion process would be attained. In this way, the effect of load increases on the performance of the high-rate digester could be observed until failure was realized.

Pilot Digester Operation

The operation of the pilot digestion system was started on June 17, 1953. At this time, the displacement period of the plant high-rate digester averaged 14 days. The pilot unit was fed at that rate. Table I describes the nature and quantity of the raw sludge added to both the pilot and plant digesters. The initial rate of feed was continued for two weeks, constituting Period 1. During July, raw sludge pumpage increased, which resulted in lowering the plant digester displacement time to 11 days. The pilot loading was accordingly increased for Period 2 to approximate that detention. This rate was maintained for a month, equivalent to about three turnovers of the digester contents at a displacement of 10.3 days. For these two periods, the pilot loading rate averaged 0.27 and 0.28 lb. of dry solids per day per cubic foot of digester volume.

At this time, the program of progressively increasing the loading rates on the pilot digester was begun, whereas the plant loading rate remained essentially constant. By this procedure, the pilot displacement time during Period 3 was lowered to 8.3 days while the solids loading rate was increased to 0.37 lb. per day per cubic foot. The pilot digester operation remained stable at this loading for about two displacement periods, after which the feed was again increased. This procedure was followed, step by step during Periods 4, 5, 6 and 7, with operation at any given loading level being continued for at least five displacement periods to insure that process equilibrium was being maintained at these increasingly critical rates of feed.

During Period 7, the pilot was receiving 1.15 lb. per day of solids per cubic foot, at the low displacement of 3.2 days. After about eight turnovers of the contents, analytical results indicated that process stability remained unaffected during the course of that period.

As may be seen in Table I, Periods 8, 9 and 10 represent displacement times under three days and loading rates up to 1.5 lb. of solids per day per cubic foot. At these higher rates of feed, failure of the digestion process occurred, fulfilling a main purpose of the experiment. Data for these critical periods are recorded in the form of 5-day averages. The course of events during this time of rapid change in digester performance is discussed later.

At the end of Period 10, the pilot digestion process was in a state of deterioration. Gas production was rapidly decreasing. It was therefore decided to lower the rate of feed. At an average displacement of 14.3 days, the pilot digester slowly recovered until, after about three weeks, normal performance was reestablished. The average conditions during this time of recovery are represented by Period 11, at the end of which this investigation was brought to a close.

The last line in Table I presents the average operating conditions for the plant high-rate digestion system during the total time of the pilot experiment. In this way the plant digester performance can be evaluated in comparison with the pilot unit, which was operated at solids loading rates up to six times as high.

TABLE II.—Results of High-Rate Digestion of Thickened Combined Primary and Activated Sludge

Period No.	Displ. Period (days)	Digester Sludge			Digester Liquor				Gas Produced in High-Rate Digester						Gas Lost (cu. ft./day)		Digestion Index (%/day)
		Dry Solids		pH	Vol. Acid p.p.m.	Alkalinity			Volume (cu. ft./day)	CO_2 Content (%)	Production			Proportion of Total Available (%)			
		Total (%)	Vol. (%)			Total (p.p.m.)	Net Produced (lb./day)	Unit, per Dry V.M. Added			(cu. ft./lb. V.M. added)	(cu. ft./lb. V.M. destroyed)	(cu. ft. gas/day/cu. ft. dig.)		Measured	Est. Total	
1	14.0	3.3	58.7	7.0	650	4,800	0.12	0.10	11.9	35.6	9.9	17.9	2.0	93	0.9	0.9	90
2	10.3	3.0	61.1	7.0	600	4,100	0.14	0.12	9.9	34.8	8.3	18.7	1.7	92	0.9	0.9	110
3	8.3	3.0	57.4	7.0	700	3,300	0.14	0.09	12.0	34.2	8.0	17.0	2.0	90	1.2	1.3	110
4	6.4	3.0	58.3	7.0	750	3,000	0.17	0.09	15.5	35.2	8.2	18.0	2.6	89	1.7	1.9	130
5	4.7	3.3	57.2	7.0	800	3,100	0.24	0.10	21.5	34.0	8.6	22.2	3.6	87	2.7	3.2	140
6	3.7	3.2	60.5	7.0	1,300	2,900	0.28	0.08	25.4	37.6	7.3	17.5	4.2	81	4.7	5.8	120
7	3.2	4.1	63.1	7.0	1,700	3,600	0.40	0.08	35.1	36.4	6.8	16.7	5.9	75	9.3	11.8	90
8	2.9	4.4	63.7	7.2	1,600	4,900	0.61	0.11	39.0	37.2	6.7	18.1	6.5	77	8.9	11.5	120
9	2.6	4.6	68.1	7.2	2,000	5,000	0.69	0.10	39.0	36.0	5.5	15.5	6.5	67	14.6	19.5	80
10	2.6	4.2	72.2	7.0	3,500	4,900	0.69	0.10	29.0	40.9	4.2	12.0	4.8	59	15.2	20.5	50
11	14.3	4.2	66.7	7.3	2,600	6,000	0.15	0.11	17.3	34.2	12.4	(27.9)	2.9	79	4.5	4.5	30
Plant	13.3	3.1	62.7	7.0	750[1]	3,600	2,900	0.09	281,000	35.8	8.5	17.4	1.6	84	50,000	52,000	41

[1] Determined for Periods 6–11 only, using same method as for pilot.

As shown in Table I, there is a seasonal variation of the raw sludge concentration and the percentage of volatile matter in the dry solids. When sewage temperatures were high, from July through October, solids concentration decreased to about 4.5 per cent while the volatile content decreased to as low as 67.7 per cent during August. This fact, together with the decreased plant gas production during those hotter months, indicates a specific loss to the sludge of the gasifiable volatile matter fraction.

Results of High-Rate Digestion

The performance of the pilot digester under the foregoing loadings is shown in Table II, which presents the data relating to the sludge leaving the digester and to the gas production.

This table reports the actual gas production data for the high-rate digester and the residual gas extractor. Since the total quantity of gas produced depended upon the sludge detention, the data were related to a common base; namely, an over-all detention of 30 days. This base was chosen only because it happened to be essentially that of Period 1. The residual gas extractor production, designated as "Gas Lost, Measured," was therefore used to estimate the gas that would have been produced in an extractor of such size as to make the over-all detention of the system 30 days. In these calculations an average digestion index of 100 per cent per day was assumed. These corrected values, represented by "Gas Lost, Est. Total" plus the high-rate digester gas production, constituted the total available gas. The proportion that the high-rate digester gas production bears to the total available was calculated and expressed in per cent.

The estimated total gas lost was then used in calculating the digestion index, previously developed as a measure of the efficiency and velocity of digestion (1). The digestion index was used to measure the rate of conversion of the potentially gasifiable matter in the high rate digester. Thus, a digestion index of 120 per cent per day would mean that the quantity of gas produced in a day is equal to 120 per cent of the quantity of gas potentially available at any moment in that tank. The digestion index may be expressed as

$$\text{Digestion Index (\%/day)} = \frac{G\,Q}{g\,V} \times 100$$

in which Q is the daily sludge volume; V is the nominal digester volume, G is the daily gas production of the digester; and g is the gas available in the sludge leaving the digester, as produced by a residual gas extractor of sufficient size.

The digestion index remained essentially constant between 90 and 140 per cent per day while the detention period varied from 2.9 to 14 days. Apparently the rate of conversion of solids to gas was dependent upon the environment, and independent of the detention time, during those periods when the process operated with stability. These values of digestion velocity indicate the solids were converted to gas in a matter of hours rather than months.

Comparison of Plant and Pilot Digesters

The criteria previously described can be used to compare the efficiencies of the plant and pilot high-rate digesters during Periods 1 and 2 when the nominal detention times were equal. During these periods, the pilot high-rate digester produced 93 and 92 per cent, respectively, of the normally available gas, whereas the plant unit produced only 83 and 85 per cent.

This comparatively lower gas producing efficiency of the plant unit can be evaluated by the respective digestion indices. That is, while the pilot unit had an average digestion index of 100 per cent per day, the index for the plant digester was but 41 per cent. Since the environmental factors of tem-

perature, pH and raw sludge composition were the same for both systems, it appears logical to assume that the inherent velocities of digestion were equal. Therefore, in order to explain this difference in digestion index, the relative degree of utilization of the digester volume should be considered. By this reasoning, the comparison indicated that the plant digester effectively used but 41 per cent of its volume as compared to the pilot digester, based on their respective digestion indices.

The foregoing comparison was made between two digestion systems operating at the same nominal loadings. It would be interesting, therefore, to compare these digesters on the basis of the same gas producing efficiency. Thus, during Periods 5 and 6, according to plant records, the plant tank, at an average displacement of 11.8 days, was producing 84 per cent of the available gas. Interpolating the data for Periods 5 and 6 (Table II), it appears that the pilot unit was simultaneously operating with the same gas producing efficiency of 84 per cent when the sludge detention time was but 4.2 days. On this basis, the plant digester was 4.2/11.8 or 36 per cent as efficient as the pilot unit in regard to tank volume utilization. These two methods of evaluation, based on gas production, are in reasonable agreement and indicate an average effective volume of 38 per cent for the plant digester.

Confirmation of this low degree of tank utilization was obtained by comparing the alkalinity concentrations of the pilot and plant digesters. Operating with the same sludge at the same time, it was found that the alkalinity concentrations of the sludge liquor in the pilot and plant units were the same when the pilot detention was 37 per cent of the nominal plant detention. When pilot detentions were greater than 37 per cent of the plant, the pilot alkalinity concentration was higher than the plant. When pilot detentions were less than 37 per cent of the plant, the pilot alkalinity concentration was lower than the plant.

A salt displacement test made in the plant tank indicated an effective tank utilization of 33 per cent. This salt test, together with the alkalinity comparison, served to independently corroborate the foregoing findings with respect to the low degree of plant tank utilization. From these data, it appears that the plant digester, if provided with means for effective mixing of its entire volume, could handle up to three times the present loading rate without any corresponding loss of gas producing efficiency.

Effect of Load Variation on Performance of the Pilot Digester

The data presented in Tables I and II cover quite a wide range of loading of the pilot digester. The unit was started at a displacement period of 14 days and 0.27 lb. of solids per day per cubic foot of volume. The loading was progressively increased until failure occurred at 2.6 days displacement and 1.5 lb. of solids per day per cubic foot. Between these limits there were marked changes in the performance of the pilot high-rate digester based on factors indicating the accumulation of undigested material.

After examination of Table II, three such factors were selected. One of these was the volatile content of the sludge solids leaving the high-rate digester. Since the ash concentration of the raw sludge was substantially constant, any marked increase in volatile content represented undigested solids. Associated with the transfer of this undigested material was the second factor—namely, the proportion of gas lost by the high-rate digester. This gas loss was obtained by subtracting from 100 per cent the value in Col. 15, Table II. The third factor was the concentration of volatile acids in the liquor.

Figure 2 indicates the relation between the displacement period and these factors; that is, volatile content,

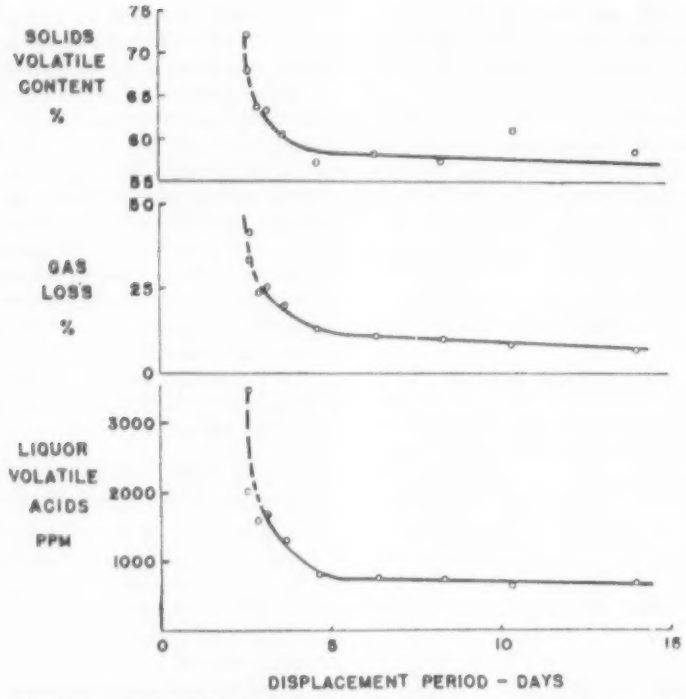


FIGURE 2.—Pilot high-rate digester performance *vs.* displacement period.

gas loss, and volatile acids concentration. These three relationships appear to be essentially similar. Each curve, as the displacement period decreases from 14 to about 5 days, shows a small linear rise, indicating an extremely limited response to this large increase in loading. On the basis of these curves, it appears that little benefit would be derived from extending the detention period beyond 5 days. Thus, at 5-day detention, Figure 2 indicates a gas loss of 12 per cent of the quantity normally available from a 30-day system. If the digester volume were doubled, that is, increasing the detention time to 10 days, about 3 per cent more gas would be produced. At 15 days detention, an additional increment of only 3 per cent would be realized.

On the other hand, as the detention time decreased below 5 days, the curves begin to rise rapidly, indicating significant accumulation of undigested material in the high-rate digester. At four days detention, the gas loss increased to 16 per cent and at three days to 25 per cent. Although there was a definite loss of gas producing efficiency between 3 and 5 days sludge detention, the process operated with essential biochemical stability between those detention times.

However, at detentions below three days, the high-rate digester rapidly accumulated load as it approached complete process failure. At 2.6 days detention, digestion was failing so fast that process equilibrium was lost. This zone of instability is represented by dashed lines in Figure 2.

It should be noted that the pH and alkalinity production of the digesting sludge were not affected by the wide range of variation in digester detention. The pH remained substantially

constant during the course of the experiment. The alkalinity appeared to depend mainly on the concentration of the volatile matter in the raw sludge, with approximately 0.10 lb. of alkalinity being generated during both thickening and digestion for each pound of volatile matter added.

Performance of Residual Gas Extractor

After passage through the high-rate digester the digested sludge was held for an equal detention period in the residual gas extractor, which was installed for the purpose of measuring the unfinished digestion. The gas production of the extractor is shown in Table II as "Gas Lost, Measured" from the high-rate digester. With respect to the recovery of the residual gas, the extractor appeared to be quite efficient. For example, during Periods 7 and 8, at an average detention of three days in both the high-rate digester and extractor, the first unit produced 76 per cent of the available gas and the second unit about the same proportion of the remainder. Thus, with an over-all detention of six days, the combined system recovered 95 per cent of the gas. On the other hand, a single high-rate digester would require 17 days detention to recover the same proportion of gas, as determined from extrapolating the gas loss curve of Figure 2.

TABLE III.—Sludge Characteristics of Residual Gas Extractor

Period No.	Displ. Period (days)	Dry Solids (%)		pH	Sludge Liquor (p.p.m.)	
		Total	Volatile		Vol. Acid	Alk.
1	14.0	2.8	60.2	7.3	450	4,700
2	10.3	2.7	59.6	7.3	500	4,500
3	8.3	2.5	58.2	7.1	600	3,500
4	6.4	2.7	57.1	7.2	600	3,200
5	4.7	2.9	56.2	7.2	550	3,200
6	3.7	2.8	59.2	7.1	700	3,400
7	3.2	3.2	61.8	7.2	800	4,300
8	2.9	4.1	60.6	7.3	700	5,400
9	2.6	4.1	64.3	7.3	900	5,500
10	2.6	3.7	67.2	7.3	1,200	5,500
11	14.3	3.2	64.5	7.4	1,200	6,400
Plant	13.3	2.9	59.3	—	—	—

The characteristics of the sludge removed from the residual gas extractor are shown in Table III. Comparing the total solids concentration and volatile content of this sludge with that from the high-rate digester, it can be seen that further digestion had occurred, especially during the latter periods of higher loading. Thus, considering Periods 7 and 8, previously cited, the volatile matter concentration entering the extractor averaged 2.7 per cent solids, whereas the sludge leaving had an average volatile matter concentration of 2.2 per cent, indicating further significant destruction of volatile matter.

The residual gas extractor was effective in reducing volatile acids, especially when the volatile solids concentrations leaving the high-rate digester were higher. It should be noted (Figure 2) that by using the separate residual gas extractor, greater efficiency was obtained in the destruction of the remaining volatile matter and the reduction of gas loss than could have been obtained by using the high-rate digester alone, enlarged to the equivalent combined volume.

As might be expected, the residual gas extractor effected a small increase in the pH and alkalinity concentration of the sludge added.

Details of Failure Episode

One purpose of this investigation was to observe the digestion process in the zone of failure. This event was realized on January 1, 1954.

Figure 3 is a day-by-day semi-logarithmic plot of the volatile acids concentration, the unit volatile matter loading, and the resulting gas production for a period of about one month prior to and following failure.

The plot starts with 19 days of loading at a detention of 3.2 days, a continuation of Period 7 which lasted

FIGURE 3.—Details of pilot high-rate digester failure episode.

for about eight displacements. It can be seen that the gas production was essentially uniform, at about 7 cu. ft. per lb. of volatile matter added. The volatile acids concentration started at about 2,000 p.p.m. and followed a slight downward trend. This period, which ended December 19, thus represented a condition of biochemical equilibrium at 3.2 days detention.

The loading was then gradually increased until on December 22 the displacement was reduced to 2.6 days. On December 24 (indicated by arrow) gas production dropped to 6 cu. ft. per pound of volatile matter added, significantly below the previous level, and continued to decrease thereafter. On the following day the volatile acids concentration suddenly rose from 1,200 to 1,900 p.p.m. (shown by arrow) and thereafter continued to increase. By January 1, gas production had fallen to 4 cu. ft. per pound of volatile matter added. This drop in gas production was accompanied by a deteriora-

tion in gas quality. The CO_2 content of the gas, previously averaging 36 per cent, increased to 45 per cent on January 1. Volatile acids concentration was approaching 5,000 p.p.m. and the sludge was becoming malodorous. The trend was toward continued breakdown of the digestion process. In the light of these facts, it was recognized that failure was virtually complete on this date (shown by arrow on loading chart) and that further high loading would make process recovery improbable.

The loading was thereupon reduced to approximate that rate which would normally produce the quantity of gas actually being generated when experimental failure occurred. This corresponded to an average detention of 14.3 days. Within a few days, the unit gas production improved and the quality recovered. However, it required some three weeks to complete the conversion of the backlog of digestible material to gas. The volatile acids concentration, which reached a peak of 5,500 p.p.m. on January 4, did not return to its previous level until January 19.

Since the pilot digester had a fixed cover, it was not possible to observe if foaming conditions were present. In any event, no operating difficulties were experienced due to foaming at any time.

On January 1, at the time of failure, the digester pH was depressed only from 7.1 to 6.9, the alkalinity remaining virtually unchanged at a concentration of 4,800 p.p.m. From these observations, it appeared that the pH and alkalinity could not be relied upon as indicators of incipient failure when digesting thickened combined primary and activated sludge.

With recovery completed about January 20, the loading was somewhat increased in order to start a duplicate run. However, the apparatus had to be released for modification and improvements. The experiment was brought to a close on January 27, 1954.

Discussion of Results

The plan of this experiment provided for the initial operation of the plant and pilot digestion systems under parallel and comparable conditions. The nominal displacement periods were made equal and the same thickened raw sludge was fed to each. Despite the apparent equality in operating conditions, there was a marked difference in digester performance. Thus, with respect to the digestion index, which may be considered a measure of the efficiency and velocity of digestion, the plant high-rate process proceeded at 41 per cent per day as compared to 100 per cent per day for the pilot digester.

From the foregoing, it was reasoned that if the pilot digester was so much more efficient than the plant digester, it should have been capable of reproducing the equivalent of the plant-scale results at much higher loadings. That this was actually the case was shown by the fact that the plant tank, operating at 11.8 days detention, produced 84 per cent of the available gas, whereas the pilot unit produced the same proportion at 4.2 days detention. Thus, from the standpoint of gas production the plant unit was only 36 per cent as efficient as the pilot. It did not appear reasonable that the fundamental biochemical processes could proceed at such widely different rates under essentially the same environmental conditions. Consideration of this discrepancy indicated that the explanation would be found mainly in the physical differences between the two units.

In this connection, the pilot digester, during the course of the experiment, did not accumulate silt or other solids which might materially reduce the active volume. The contents were well mixed by a mechanical stirrer continuously rotating at 30 r.p.m. Temperature was uniform

throughout the tank. Therefore, the unit may be considered to have substantially utilized its nominal tank volume.

On the other hand, the plant unit was found to contain a deposit of silt and heavy gelatinous digested sludge, as well as floating material, adding up to roughly one-third of the nominal tank volume. Recirculation by external pumps was not an effective means of mixing, as borne out by sludge temperature tests. Consideration of these factors indicated that the lower efficiency of the plant digester was due to the use of only a fraction of its volume. Therefore, if the entire volume could be effectively utilized, it would permit almost tripling the loading on the plant digester, already operating at 0.5 cu. ft. per capita.

Relative to the loadings applied to the pilot digester, it should be remembered that the tank was fed uniformly a thickened combined primary and activated sludge at an over-all concentration higher than the normal practice. For these favorable conditions, it is possible to select the optimum digester detention from Figure 2.

From inspection of Figure 2 it is apparent that increasing the size of the digester above that required for a displacement period of 5 days will not appreciably increase gas production efficiency. On the other hand, as the detention period was reduced below 5 days, the efficiency decreased rapidly, although the process operated with biochemical stability to a displacement of about 3 days. Thus, for the digestion of this mixture of thickened primary and activated sludge, 5 days of detention with complete tank utilization would appear to be desirable. This would be equivalent to providing a high-rate digester capacity of about 0.2 cu. ft. per capita based on the operation of the Bowery Bay plant with its connected population of 350,000.

From Figure 2 it may be seen that attempting to recover the lost gas by increasing the size of a single high-rate digester is not economical. However, the residual gas may be readily extracted from the sludge by a relatively small following unit. This residual gas extractor will almost eliminate gas losses at an operating detention as low as 3 days. However, consideration should be given to providing two identical digesters, which will allow for reversibility of operation. At an effective detention of 5 days in each tank, such a system should recover 98 per cent of the normally available gas at a total digester capacity of 0.4 cu. ft. per capita.

In connection with the failure episode, it was pointed out that when the loading rate increased to almost 1.2 lb. of volatile matter per day per cubic foot of digester and the displacement period was reduced to 2.6 days, digester performance deteriorated rapidly. With gas production declining and volatile acids concentration steadily increasing, it was found necessary to lower the feeding rate to prevent irremediable failure. It appeared that some element of the bacterial activity could not cope with this elevated loading rate. Whether this failure may be attributed to the inordinately high rate of feeding of gasifiable volatile matter per unit volume or to the excessive displacement of necessary bacteria in the outgoing volume could not be ascertained from these data. It is anticipated that additional experiments now in progress relating to the digestion of more highly concentrated thickened combined primary and modified aeration sludges may aid in determining the critical factor. The digestibility of this sludge of different composition would also be evaluated by such investigation.

Acknowledgments

The author is especially grateful for the assistance and advice of Richard H. Gould, Director of the Division of Sewage Disposal, and to Commissioner Frederick H. Zurmuhlen, whose deep

interest in improved techniques made these tests possible.

Thanks are extended to Hubert Becker, Jr., in charge of the Bowery Bay plant, and his operating staff for their assistance in setting up and operating the pilot apparatus, and to R. B. Wolf, R. Epstein and I. Reichman for their daily supervision of the operation and analysis of samples.

A. H. Chasick and M. Lang gave valuable assistance in the preparation and presentation of the data.

References

1. Torpey, W. N., "High-Rate Digestion of Concentrated Primary and Activated Sludge." THIS JOURNAL, **26**, 4, 479 (Apr., 1954).
2. Torpey, W. N., "Concentration of Combined Primary and Activated Sludges in Separate Thickening Tanks." *Proc. Amer. Soc. Civil Eng.*, Separate No. 443 (May, 1954).
3. "Standard Methods for the Examination of Water and Sewage." 9th Ed., Amer. Pub. Health Assn., New York, N. Y. (1946).

DISCUSSION

By Harry E. Schlenz

President, Pacific Flush Tank Co., Chicago, Ill.

Although the following discussion may appear to be quite critical of Mr. Torpey's conclusions, it is not intended in any way to detract from the excellent experimental procedures upon which he has reported, since he has pointed out many facts which are important to the operating staffs of sludge digestion installations.

At the 1953 Annual Meeting of the Federation, two papers and corresponding discussions were presented reporting upon pilot-plant digestion studies and carefully controlled experimental procedures with plant size digesters (1)(2). From one of the papers, broad claims have been made that present digester capacity standards can be reduced by two-thirds, while the other paper left the impression with the audience, and others who have since read the published article, that 0.5 cu. ft. of digester capacity per capita is adequate for combined primary and activated sludge if properly concentrated. Mr. Torpey's present paper suggests that 0.2 cu. ft. of digester capacity per capita might be satisfactory and recommends a design value of 0.4 cu. ft. per capita based upon small pilot-scale experiments.

That such conclusions are misleading, when accepted without considering many other factors of practical plant operation, is evidenced by the experience of a competent design engineer in the South. He had completed a report for the additions to an existing treatment plant for a moderately large city, involving a 50 per cent increase in the digestion capacity. Certain official personnel of that city who heard or read these mentioned articles concluded that the existing digestion capacity was more than adequate, despite the increase of load over the original design basis, and have held up for more than a year the completion of the designs for additional capacity. The consulting engineer found it necessary to convince the city officials, through carefully controlled operating procedures set up at the plant, that the practical factors of operation, the method of disposing of the sludge, and the improbability of the city providing sufficient trained technical operating personnel to carry out the controlled operating procedures, required the additional capacity which was being recommended.

Later in this discussion it is hoped to establish some of these practical considerations by reference to data which have been consolidated into comparative tables and charts.

The writer definitely agrees with the basic thought expressed by Mr. Torpey that the digestion of sewage sludge should be on a controlled basis. In fact, a similar plea by the writer (3) in 1944, in which the importance of frequent volatile acid determinations was emphasized, went unheeded. Torpey shows that pH and alkalinity of digester contents cannot be relied upon as indicators of incipient failure, whereas the variations in volatile acid concentration provide a definite indication and guide to the condition of the digester.

If plant operators obtain from papers such as this the importance of careful control of the operation of digesters, they can show definite improvement in effectively using the available capacity.

Comparison of Plant and Pilot Digesters

Mr. Torpey emphasizes a determination designated as "digestion index," but it appears that this is an exceedingly misleading measure of the efficiency and velocity of digestion. Torpey makes a comparison of the plant digesters and pilot digesters for Period 1 when the detention time and raw feed were reported to be the same. Therefore, in the basic formula for "digestion index"—

$$\%/\text{day} = \frac{G\,Q}{g\,V} \times 100$$

in which G is the daily gas production, Q is the daily raw sludge feed volume, g is the gas available in the sludge leaving the digester and V is the nominal digester volume—the value of Q/V would be the same in each case. This would leave the remaining ratio, G/g, as the comparison of the difference in digestion efficiency, which Torpey gives as 90 per cent for the pilot digester and 41 per cent for the plant digester, indicating that 90 per cent of the pilot digester capacity was effectively used, whereas only 41 per cent of the plant digester capacity was effective.

This comparison appears to be out of line with a comparison of the gas production for the same period, in which it is reported that 93 per cent of the total calculated available gas was obtained from the first-stage pilot digester and 83 per cent of the total calculated available gas was obtained from the first-stage plant digester. (In fact the first-stage plant digester showed a value of 84 per cent for a daily average of 224 days of data, compared with the value of 93 per cent for the first-stage pilot digester for a daily average of 14 days of data.)

It would appear more logical to conclude that the comparison of the effective use of the digester capacity for the same detention period and same feed of raw sludge would be the relationship of the 93 per cent and 84 per cent values. This would mean that instead of the plant digester being rated at about 45 per cent of the effectiveness of the pilot digester, it would be calculated to be about 90 per cent as effective in rate of conversion of solids to gas as the pilot digester. Furthermore, it is important to consider that the average daily gas production for the plant digester was based on an operation period 16 times as long as that for the pilot digester from which the average daily gas values were used for the comparison. The average for the plant digester for the longer period would be more greatly affected by seasonal and daily variations in feed, temperature and other factors. A comparison for exactly the same 14-day period would have been more desirable in comparing the operation under similar conditions.

This analysis seems to be supported by the values given in Table I, where it is calculated that the plant digester showed a reduction in volatile matter of 42.6 per cent as the average for the entire 224-day period, as against a reduction of 52.2 per cent for the pilot digester, based on an average of only

14 days at the same loading. When the secondary phase of the digestion is included, the plant digester system showed a reduction of 50.1 per cent as against the pilot digesters showing 49.3 per cent reduction of volatile matter for Period 1.

Furthermore, if the experimental routine is carefully considered, it would appear that some of the reported difference between the efficiencies of the pilot and plant digesters could be explained. For instance, raw feed to the pilot digester consisted of a measured portion of the thickened combined primary and activated sludge taken at one time and divided into 12 equal parts of approximately uniform composition to be fed at 2-hr. intervals. On the other hand, the plant digester received a more variable quantity and quality of feed, which was compared by averaging of determinations. Based on records for other plants, it would be expected that the actual daily loading of raw sludge on the plant digester must have varied quite widely.

It is difficult to follow Mr. Torpey's statement that "confirmation of the reported low degree of tank utilization of the plant digester was obtained by comparing the alkalinity concentrations of the pilot and plant digesters," concluding that since the alkalinity concentrations were the same when the pilot digester was operated at a detention of 37 per cent of the nominal plant digester detention, the relative effective use of digester capacity would follow this same percentage. The alkalinity data presented in Table I do not support such a conclusion.

On the basis of the unsubstantiated case set up in regard to the comparison of efficiencies of the pilot and plant digesters, Mr. Torpey concluded that the plant digester, if equipped with effective mixing of its entire volume, could handle up to three times its high loading without loss of gas producing efficiency. Considerations of a practical nature would involve the comparison of the mixing of a small 21-in. diameter, 36-in. deep basin with an 82-ft. diameter digester having a 35-ft. liquid depth, a volume relationship of 1 to 30,000.

Consideration is given by Mr. Torpey to the fact that a large digester, over an extended period of time, loses

TABLE IV.—Comparison of Reduction in Volatile Solids by Digestion

Bowery Bay Plant[1]							Expected Reduction in Volatile[2] (%)
Period No.	Days	Volatile Solids in Sludge (%)			Reduction in Volatile (%)		
		Raw Feed	From 1st Digester	From 2nd Digester	By 1st Digester	1st and 2nd Digester	
1	14	74.9%	58.7%	60.2%	52.2%	49.3%	73%
2	30	73.3	61.1	59.6	42.8	45.7	70
3	15	67.7	57.4	58.2	35.9	33.9	61
4	40	71.3	58.3	57.1	44.0	46.3	66
5	25	73.6	57.2	56.2	52.0	53.8	71
6	35	73.7	60.5	59.2	45.1	47.9	71
7	25	75.2	63.1	61.8	43.6	46.7	75
8	5	78.0	63.7	60.6	50.6	57.2	80
9	5	78.2	68.1	64.3	40.1	49.6	80
10	5	80.9	72.2	67.2	38.5	51.4	85
11	25	80.0	66.7	64.5	49.8	54.5	84
Plant	224	74.5	62.7	59.3	42.6	50.1	73%

[1] Calculations from data of Tables I, II, and III, as compared with data from other plants recorded in Figure 1.

[2] Normally expected reduction in volatile, based on original raw volatile content.

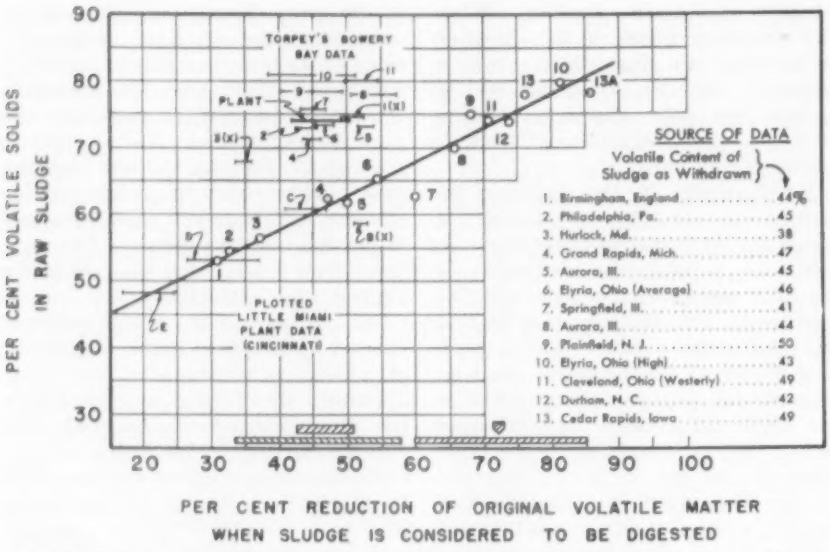


FIGURE 4.—Comparison of reduction in volatile matter by digestion: results of Torpey high-rate digestion and Little Miami plant data plotted on typical curve as prepared in 1941 from other plant data.

some effective capacity due to deposits of silt, heavy gelatinous sludge, and accumulation of floating material. The mixing of a smaller volume (1/30,000th) in the pilot digester causes small daily increments of such space-using materials to be displaced from the unit.

The first curve of Figure 2 appears to be incorrect when comparing the volatile content of the digested sludge for the various detention periods without regard to the variable volatile content concentration of the raw feed reported for the various periods. The values recorded in Table IV shows an entirely different relationship without any definite pattern, when the percentage reduction in volatile matter is tabulated for the same periods to take into account the difference in volatile content of the raw sludge.

It is believed that the conditions at Bowery Bay and other New York City plants which might justify "high-rate" digestion are different from those in the majority of plants. Since the digested sludge is barged to sea, the need for "ripening" of the sludge, so that it may be easily filtered or dried on sand beds, is not involved. There is also the question of storage, with the digester system serving as a "take-up" in the plant, so that vacuum filtering or drying operations can be done on a periodic basis.

Degree of Digestion

It appears, from a comparison with the data on digestion for other representative plants, as based on reduction of volatile matter by digestion, that the data for the Bowery Bay plant "high-rate" operation shows a much lower degree of digestion. Figure 4 shows a relationship between the percentage of volatile in the raw sludge and the percentage reduction of this original volatile matter when the sludge is considered to be digested as determined by established criteria. The curve, published in 1941, has been checked against the data for many plants since that time, and the general relationship as shown has been found to be on the conservative side.

The data presented by Torpey have been plotted on this curve and are identified by periods and range of reductions of volatile solids based on both the first and second stages of digestion. It will be noted that the reduction in volatile solids from Torpey's data on "high-rate" digestion ranges from 33.9 to 57.2 per cent for both primary and secondary digestion, whereas the curve would indicate an expected volatile reduction of 60 to 85 per cent for the reported range of original raw volatile. The average data for the plant digesters are shown as a maximum reduction of 50.1 per cent, whereas the curve indicates an expected reduction of approximately 72 per cent. The comparative values for the different periods of Torpey's data are also recorded in Table IV. Figure 4 also contains the recorded data for Cedar Rapids, Iowa, and the Little Miami plant at Cincinnati, Ohio, where higher than normal loadings in the first-stage digesters have resulted in volatile solids reductions which follow the typical curve.

High Loadings at Other Plants

Figure 5 shows the plotted data for an 8-month average at Cedar Rapids as prepared in 1936, with additional data for 1942–3. The latter data show unit loadings of 0.249 lb. of total solids and 0.197 lb. of volatile solids per cubic foot per day for a 12-month average, which compares favorably with the plant-scale data at Bowery Bay. No special concentration or mixing means were provided at Cedar Rapids, although the sludge is high in volatile matter due to its content of packinghouse wastes and is probably more readily digestible than normal domestic sludge.

Table V is a summary of the data for the Little Miami plant at Cincinnati, Ohio, where considerable difficulty was experienced early in 1954 in the initial starting of the digesters. Uncontrollable acid conditions developed in all four digesters, with the result that they had to be cleaned out, and each one brought into proper operation by seeding, progressive feeding starting

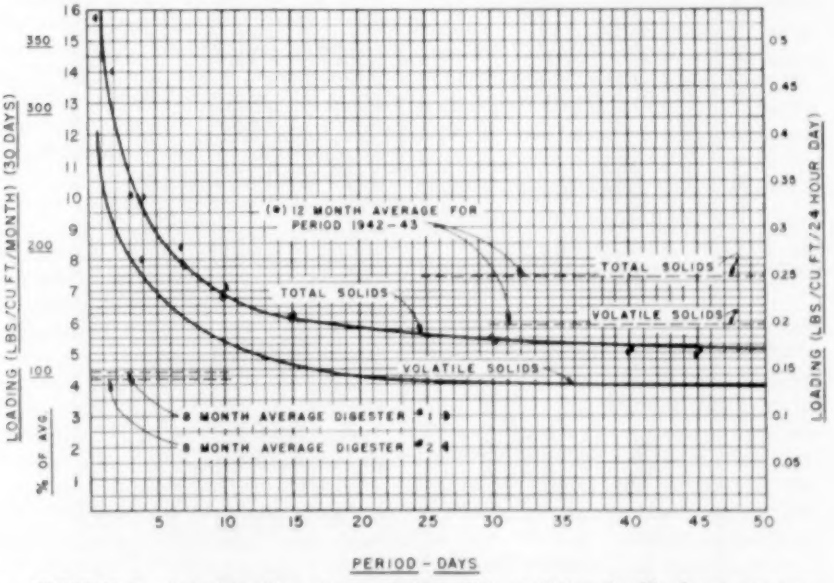


FIGURE 5.—Actual loading of raw sludge solids at Cedar Rapids, Iowa, sewage treatment plant between February and September 1936.

TABLE V.—Digestion Data, Little Miami Plant, Cincinnati, Ohio

Period[1]	Dates (1954)	No. of Days	Raw Sludge Data				Loading Rate, Dry Solids				Primary Digester			
			Feed (cu. ft./day)	Displacement (days)	Dry Solids (%)		(lb./day)		(lb./cu. ft./day)		Volatile Acids (p.p.m.)	Alkalinity (p.p.m.)	pH	Temp. (° F.)
					Total	Vol.	Total	Vol.	Total	Vol.				
A	7/28–8/19	23	1,148	65	8.10	58.6	8,100	4,747	0.108	0.64	111	2,303	7.1	88
B	8/20–9/8	20	2,400	31	7.49	60.4	11,215	6,782	0.150	0.90	177	2,565	7.2	90
C	9/9–9/22	14	3,220	23	8.33	57.8	16,770	9,699	0.225	0.130	88	2,710	7.2	90
D	9/23–10/4	12	5,467	13.6	9.30	52.8	31,580	16,670	0.423	0.223	153	2,604	7.2	90
E	10/5–10/11	7	5,600	12.2	9.35	47.9	32,745	15,630	0.481	0.230	106	2,870	7.2	90

Period[1]	Gas Produced, Primary				Transferred Sludge			Gas, Secondary		Secondary Digester				Digested Sludge			Total Gas
	CO_2 (%)	(cu. ft./day)	(cu. ft./lb. vol. added)	(cu. ft./cu. ft. of dig./day)	Solids (%)	Vol. (%)	Vol. Red. (%)	(cu. ft./day)	(cu. ft./lb. orig. vol. added)	Volatile Acids (p.p.m.)	Alkalinity (p.p.m.)	pH	Temp. (° F.)	Solids (%)	Vol. (%)	Red. Vol. %	(cu. ft./lb. vol. added)
A	32	39,270	8.27	0.52	—	—	—	—	—	—	—	—	—	—	—	—	—
B	34	61,380	9.05	0.82	3.82	42.1	52.1	16,445[2]	2.42	137	3020	7.2	90	6.59	42.5	51.4	11.47[2]
C	34	76,700	7.91	1.03	4.46	44.9	40.5	10,030	1.03	68	2920	7.3	90	6.69	42.5	46.0	8.94
D	33.5	120,843	7.25	1.62	5.83	45.2	25.0	19,009	1.14	41	2856	7.4	86	7.86	42.3	36.7	8.39
E	33.7	135,300	8.65	1.99	6.87	43.4	16.6	26,011	1.66	50	2923	7.4	87	7.35	40.9	24.9	10.31

[1] Period A:—All four digesters taking equal portions of raw sludge feed. Period beginning 71 days after seeding and initial feeding of digester 1.

Periods B and C:—Digesters 1 and 3 as primaries, with 2 and 4 as secondaries. Data are for digester 1 and corresponding digester 2 as secondary. Average volume of digester 1 was 74,700 cu. ft.

Periods D and E:—Full raw solids load to digester 1; transfers mainly to Nos. 2 and 4 operating as secondaries. Average volume No. 1 during Period D = 74,700 cu. ft.; during Period E = 68,100 cu. ft. No. 3 not fed, so as to observe rate of gas production from residual sludge in tank.

[2] Layover of solids in No. 2 from previous raw sludge additions accounts for high gas production.

with a low rate, and careful daily checking of the volatile acid concentration. The data, recorded by periods during a total of 76 days prior to October 11, 1954, show some interesting trends. Period D indicates a loading of 0.423 lb. of total solids, or 0.223 lb. of volatile solids, per cubic foot per day for 7 days, during which period all of the plant production of raw sludge was fed to one digester.

During Period E, the primary digester, receiving all of the raw solids, was further reduced in volume to an average of 68,100 cu. ft. by lowering the operating range of the floating cover. During this 7-day period the loading rate per cubic foot per day was 0.481 lb. of total solids, or 0.230 lb. of volatile solids, with a displacement period of 12.2 days.

Many interesting facts obtained from this plant-scale operation are beyond the scope of this discussion, but the low range of volatile acid concentration and the reasonably high alkalinities under the high raw solids loading should be noted.

During Periods D and E the volatile solids concentration in the raw feed dropped appreciably, probably due to the return of low volatile solids in the liquor from the elutriation tanks prior to incineration, which had been started during Period D. Although the recycling of the lower volatile solids did not result in a reduction in the amount of gas produced per pound of volatile added to the digester system, it showed a disproportionate effect on the reduction of volatile as calculated by assuming constant ash. Additional studies are being made in this regard to determine if the recycled portion of the volatile solids can be counted upon for the production of gas in such large quantities when returned in the raw sludge to the primary digester.

It should be pointed out that this demonstration, indicating that high unit loadings can be maintained in the plant-scale operation of digesters, is dependent upon the building up of the digester to peak bacterial activity, and is made possible only with additional technical supervision of the operating personnel and laboratory staff. It is comforting assurance that additional capacity is available in the remaining digesters to receive some of the load in case of failure to maintain the high effectiveness of digestion. If the digestion action is lost, due to the entrance of some unusual product of toxic nature or wide variation in composition of the raw sludge, or by a temporary laxity on the part of the operating personnel, it has been shown by many experimenters, including Torpey, that it is necessary to reduce the load materially, or even resort to an entirely new start of the digester with progressively increasing feedings at an initially low rate.

Despite the high loadings which have been carried in the single primary digester at the Little Miami plant, the plant operating personnel have demonstrated the need for the remaining digester capacity to provide a sludge which is concentrated and filters well, without excessive chemical conditioning, and allows storage capacity to reduce filtering operations to 3 days per week. In fact, until the recently reported periods the secondary digestion capacity has carried a high accumulation of digested solids due to the necessity of storing such solids while the elutriation tanks, vacuum filters and incinerators were being properly coordinated to handle the digested sludge.

Due to the rather close control of operational procedures and additional daily analyses required for the present "high-rate" digester loadings on the one tank in the system, it has been indicated that as soon as the high loading experiments are completed, the operating personnel will be satisfied to use the existing digester capacity as designed, without any thought that it is excessive. Two digesters will be used as primaries at one-half the pres-

ent loading, and two used as secondaries.*

Variations in Raw Sludge Production

Since the digester loadings per cubic foot per day are expressed as an average, it is important that variations in raw sludge production be considered in relating such loadings to the design of sludge digestion facilities. This is especially true if short periods of detention are being considered. With reference to Figure 6, it will be noted that for a 5-day detention period the amount of sludge to be handled may be 240 per cent of the average. Even if the raw sludge is stored for a full 24-hr. in sludge concentration devices, the maximum sludge production for a 5-day period might be as much as 225 per cent of the average. The longer the detention time, the lower the allowance for excess sludge production will be in figuring the maximum loadings which might be handled.

Concentration of Digested Sludge

Mr. Torpey emphasizes the importance of the concentration of the raw sludge, but disregards the relatively low concentration of solids reported in the sludge from the secondary digesters, with a plant average of 2.9 per cent and with pilot-plant averages of from 2.5 to 4.1 per cent.

Backmeyer (5) writes, "I would reemphasize the importance of solids concentration in disposal of the digested sludge. It is one thing to get 85 per cent of the gas production in a primary tank operated at high loadings, and an entirely different problem to prepare this material for economical final disposal. I am unable to think of a single final disposal system wherein

* D. P. Backmeyer, plant superintendent, indicates that this return to normal design operation was started on October 15, 1954, four days after presentation of this discussion.

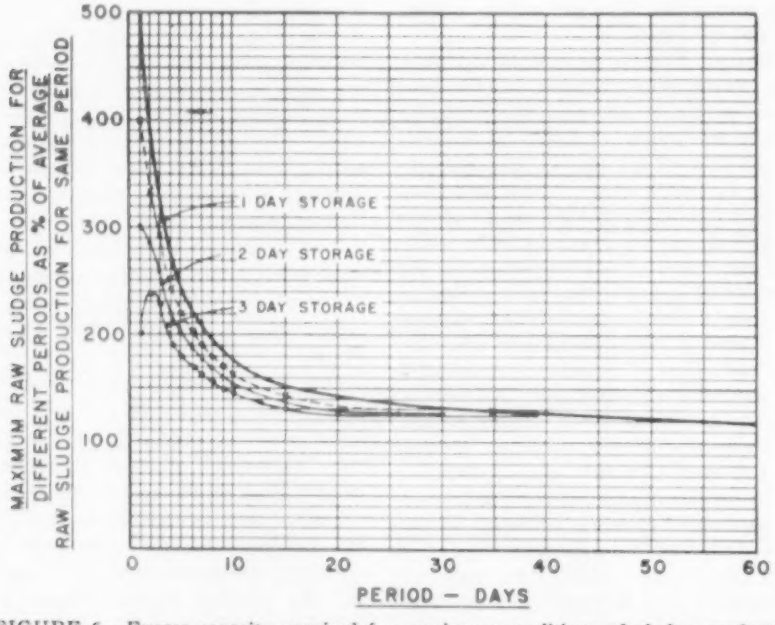


FIGURE 6.—Excess capacity required for maximum conditions of sludge production. (Prepared from data collected by R. A. Allton, 1932, representing a composite study of peak loads obtained from data of large American cities.)

TABLE VI.—Capacities for Sludge Concentration, Digestion and Storage; Bowery Bay Plant, New York, N. Y.

Plant Units	Design Pop.	Sludge Facilities (cu. ft.)				
		Conc.	Dig.	Storage	Total	Per Cap.
Existing	350,000	47,000	720,000	50,000	817,000	2.33
New	—	190,000	760,000	70,000	1,020,000	—
Total	1,000,000	237,000	1,480,000	120,000	1,837,000	1.84

it is not advantageous to have a high solids-low moisture ratio in the finished liquid sludge. At the Little Miami plant, the ferric chloride requirement in the vacuum filter dewatering of the digested sludge is proportional to the alkalinity of the sludge liquor and to the undigested organics remaining in the sludge. Solids concentration and complete digestion is therefore very important."

It would also appear that a greater concentration of the digested sludge would be important at the Bowery Bay plant, where barging-to-sea involves an expensive operation.

It is possible that the sludge as received at the Bowery Bay plant, in providing a rather high initial rate of gas production, may be more readily digestible to the degree indicated for the reduction of volatile matter, than is the case of sludges at other installations where the percent reduction of volatile is shown to be considerably greater. The volatile acid content of the raw sludge, reported to be from 1,400 to 2,000 p.p.m., seems to be rather high. The raw sludge at the Little Miami plant (Cincinnati) showed a volatile acid concentration of 300 p.p.m.

Practical Considerations

Although the conclusions as expressed by Mr. Torpey seem to indiper capita is adequate for the digestion of concentrated primary and acticate that 0.4 cu. ft. of digester capacity vated sludge, it is interesting to note that new facilities to be provided at the Bowery Bay plant (Table VI) will provide 1.48 cu. ft. of digester capacity per capita based upon a 1,000,000 design population, which must include some allowance for the future, plus an additional 0.36 cu. ft. of capacity for sludge concentration and short period storage, for a total of 1.84 cu. ft. per capita.

Since Mr. Torpey has expressed digester capacities in terms of "cubic feet per capita" in drawing his conclusions, it should be noted that the data show that at the Bowery Bay plant the dry solids added to the digesters figured to be only 0.126 lb. total solids and 0.944 lb. volatile solids per capita. For the normal activated sludge plant, a per capita sludge production as much as 50 per cent greater than these values might be expected, which would have a decided effect on digester capacity allowances expressed in terms of cubic feet per capita.

A review of the design capacities for activated sludge plants built during the period 1928–1936 shows digester capacity allowances as low as 1.7 cu. ft. per capita. Apparently such capacities have been found to be inadequate, due, in large measure, to the fact that municipalities did not provide sufficient technically trained operating personnel to properly control the plant operation. The pendulum has now swung to the point that State Boards of Health require design allowances ranging from 4.0 to 6.0 cu. ft. per capita for the digestion of activated sludge.

In 1951, on the basis of digester loading data for a number of repre-

sentative plants, it was definitely indicated (4) that such design allowances could be reduced.

For further emphasis, it should be stated that if better operational control is obtained at sewage treatment plants, the foregoing required digester capacities can be reduced materially, but not to the point suggested by recent articles based on experimental data, since such suggested values do not take into consideration other important design factors requiring more liberal capacity, including the following:

1. Variations in the quantity and quality of the sludge solids.
2. Provision of storage beyond digestion periods for the ripening and concentration of the undigestible portion so that it will drain well on vacuum filters and sand beds, as well as storage to allow periodic drying operations rather than more continuous withdrawal of sludge.
3. Allowances to offset disrupting influences caused by toxic wastes by providing space for sludge to be handled while the digester system is being returned to peak performance.
4. Compensation for the lack of trained technical personnel and for careless operational control.
5. Provision for increased population loads beyond the design population for which capacities are provided, since provision of additional facilities normally lags well behind the period when the facilities are found to be overloaded.

In conclusion, Mr. Torpey's paper presents a challenge to the sanitary engineering profession, and it is hoped that plant operators will be stimulated to attempt better control of the sludge digestion facilities under their care. However, the foregoing discussion should be interpreted as a practical warning that designs and selection of sludge digestion capacity must be based upon criteria of many day-by-day operational problems and the many imponderables in sewage character and sludge digestion phenomena, and at the same time provide for the effective performance of the entire treatment plant, of which the sludge digestion facilities comprise only an integral part.

References

1. Morgan, P. F., "Studies of Accelerated Digestion of Sewage Sludge." THIS JOURNAL **26**, 4, 462 (Apr., 1954).
2. Torpey, W. N., "High-Rate Digestion of Concentrated Primary and Activated Sludge." THIS JOURNAL, **26**, 4, 479 (Apr., 1954).
3. Schlenz, H. E., "Controlled Digestion." THIS JOURNAL, **16**, 3, 504 (May, 1944).
4. Schlenz, H. E., "What You Should Know About Sludge Digestion." *Pub. Works*, **82**, 10, 67 (1951).
5. Backmeyer, D. P. Private communication (1954).

DISCUSSION

By H. HEUKELEKIAN

Department of Sanitation, Rutgers University, New Brunswick, N. J.

This very important contribution is going to dominate the thinking and practice in regard to sludge digestion for many years to come. The present paper does not stand by itself, but should be viewed as a part of a new approach to sludge digestion. It must be viewed in conjunction with other contributions on the subject of accelerated digestion made by Morgan and Torpey, as referred to by Mr. Schlenz. In the latter paper the results of digestion of all the sludge captured at the Bowery Bay plant in one of the four available digesters were reported. Mixtures of both primary plus modi-

fied aeration sludge and primary plus activated sludge were digested for various periods. This discussion is based on the digestion of primary and activated sludge in the previous and present papers presented by Mr. Torpey. One has to go even further back than the periods of experimentation reported in these papers. It is necessary to start with the design and early period of operation of this plant.

The plant was designed with digestion tank capacity of 2.1 cu. ft. per capita. During the period when the plant was operated on a step aeration basis and digesting the primary and activated sludge, difficulty was uncountered in obtaining supernatant liquor and it became necessary to reduce the volume of activated sludge fed to the digesters. The indications on this basis were that a digester capacity of 3.5 to 4.0 cu. ft. per capita was required for the digestion of all primary and activated sludge produced at this plant. This corresponds to the accepted capacity allowance for the digestion of solids produced by activated sludge plants of 4 to 6 cu. ft. per capita.

Under these conditions, the normal procedure would have been to build additional digestion tanks. If an attempt were to be made to digest the sludge in the four available digestion tanks, experiments designed to accelerate digestion would have been undertaken first in the laboratory, followed by a pilot plant, and finally application on a plant-scale basis.

This normal course of events was not followed, but actually was reversed. All of the sludge was digested in one of the existing digestion tanks, but before the large-scale plant work could be attempted certain other prerequisites had to be met. A way had to be found for thickening of the sludge mixtures.

Once this was accomplished one of the necessary important conditions for high-rate digestion had been fulfilled. One tank out of four was loaded successfully with all the primary and activated sludge captured at the plant after thickening. According to the parameters of digestion commonly employed—pH value, volatile matter destruction, volatile acids, and gas production—the sludge could be considered well-digested. As far as the published records go the plant has been operated with one digestion tank, not only during the period reported in the previous paper (6 months), but also during the period of pilot-plant experiments covered in this paper (6 months). It should be emphasized that this was plant-scale operation and not pilot or laboratory tests. In other words, the plant was successfully operated on a 0.5-cu. ft. per capita basis, or at unit loading of 0.18 lb. volatile solids per cubic foot per day. Since it was not possible either to increase the quantity of sludge or to decrease the size of the tank, pilot-plant work became necessary to determine what maximum loadings or minimum capacities could be attained.

The pilot-plant experiments are thorough and the results are complete. They covered a period of more than 6 months. The feeding rates were increased successively after a sufficiently long period of operation at a certain level to indicate the stability of the process, until the feeding rate reached a point where failure occurred. This occurred at 2.6 days displacement period, or at a unit loading of 1.2 lb. volatile solids per cubic foot per day. The results indicate a safe maximum loading equivalent to 0.2 cu. ft. per capita or a loading of 0.4 lb. of volatile solids per cubic foot per day. At such a loading, about 90 per cent of the gas was recovered.

A number of important questions arise, as follows:

1. How are such high loadings possible?

2. Can the results obtained from a pilot plant be translated to large-scale tanks?

3. What problems does such high-rate digestion create?

The success of the high-rate digestion seems to have been achieved by simultaneous control of the following conditions:

1. Sludge thickening.
2. Effective utilization of tank volume.
3. Uniform feeding of raw sludge.

Maintenance of optimum temperature is generally accepted as a precondition for increasing the rate of digestion. The factors referred to seem to be in retrospect obvious and simple preconditions for accelerated digestion. Nevertheless, no one in the past had put all these necessary requirements together with the purpose of increasing the loading. Fischer, for instance, in the early 1920's demonstrated that thickened sludge (18 per cent) could be digested, but his work was on equal loading basis of 6, 12 and 18 per cent raw sludge. The result was that, starting with a displacement period of 40 days for 6 per cent sludge, sludge thickened to 18 per cent had a displacement period of 120 days. The real benefits of thickening were, therefore, not materialized in increasing the loading. Similarly, other workers studying digestion have missed the potentialities of high-rate digestion because they were working with one variable at a time. One obstacle of obtaining high loadings in sludge digestion in the laboratory has been the batch process. Making an initial mixture of ripe sludge and fresh solids where a 30- or 40-day quota of fresh solids is added all at once does not reproduce the conditions prevailing with incremental feeding. An initial overloading and glut, with subsequent starvation conditions, is not conducive to maintaining a uniform maximum rate of digestion.

In the large tank work Mr. Torpey attempted to obtain maximum utilization of tank capacity by recirculation of the sludge from the tank to the raw sludge line. Although this method gave an intimate mixing of the raw sludge with the ripe seed sludge, it was not ideal for maximum utilization of tank capacity. Calculations show that despite the recirculation, only one-third of the capacity of the large tank was being utilized. The mechanical stirring in the pilot digesters gave more effective mixing and utilization of tank capacity. Whether a mechanism for effective mixing of large tanks can be developed remains to be seen.

Uniformity of feeding appears to be another important factor. Thickened sludge was fed at intervals of 30 to 60 min. Additional work on this problem is needed to establish the optimum rate of feeding. In general, it would appear that as the digestion is pushed to the maximum rates, the necessity of continuous feeding becomes more important. The thickener serves as a reservoir of raw solids.

Effective utilization of tank capacity, uniform feeding, and intimate contact between the food and microorganisms, as prerequisites to high-rate digestion, have their parallel in the development of high-rate trickling filters, which became possible only with the effective utilization of space and volume by uniform distribution of sewage and more effective utilization of time by more continuous application of sewage. Thickening of the sludge or increased concentration of food is an additional factor in intensifying the biological activities in sludge digestion which is not feasible in the treatment of sewage by trickling filters. The ability to void the excess sludge at will is another important departure between the parallel of high-rate digestion and high-rate biological filtration. The inability to obtain positive control over the discharge of excess biological growth in high-rate filters imposes a serious limitation to the application of even higher loadings.

In any biological treatment process,

whether anaerobic or aerobic, when these environmental and engineering factors are controlled, microorganisms seem to be able to adjust themselves to a higher population level and seemingly do more work than was deemed possible. It has been pointed out that microorganisms do not need rest periods. The reason for less than maximum efficiency is not due to biological failure, but rather to failure to exploit the activities of microorganisms to the maximum by not providing them with the proper environmental conditions. Biological failure is naturally possible if there is some inhibiting agent in the food material. Even in the absence of such inhibiting materials biological failure will take place beyond a certain maximum rate of feeding, even under ideal conditions, as it did in the pilot-plant experiments when the loading exceeded 1.2 lb. of volatile solids per cubic foot per day at a displacement time of 2.6 days.

It is interesting to speculate as to why failure occurred at this point; whether the critical factor was loading *per se*, or displacement time. In any biological process, time is a factor and the specific time required to complete a process is dependent on the rate of multiplication or generation time of the organisms. It is possible that the generation time of some essential organism in sludge digestion, such as the methane bacteria, is in excess of 2.6 days. If this is the case, the organisms could not attain maximum population level because the displacement time is shorter than the generation time.

On a practical level, as in any other new and important development, the paper raises a number of problems and questions which can only be answered by additional work and experience. It will require years of application, experience and development to encounter and solve the problems arising from as significant and striking a departure from conventional practice as this. Anticipation of such problems and difficulties is no reason for rejecting the future possibilities of this process. The problems and difficulties are not insuperable; neither are they beyond the ingenuity of competent sanitary engineers to solve. The following are some of the limitations and problems connected with the application of high-rate digestion:

1. The process has its greatest appeal for the larger plants.
2. The dewaterability of sludge from high-rate digestion should be determined.
3. The storage capacity requirement of digested sludge for various methods of sludge disposal should be worked out.
4. A study should be made of the effect of interruption of feeding for various periods on the subsequent digestion.
5. Storage capacity requirement for feeding raw sludge at a continuous rate with fluctuating solids received and captured should be determined.
6. Development of an effective method of utilization of tank capacity by mechanical means is required.

DISCUSSION

By Henry R. King

Senior Civil Engineer, The Sanitary District of Chicago, Ill.

Mr. Torpey is to be commended for instigating and conducting the experimental work at the Bowery Bay plant on high-rate digesters. The data obtained are of considerable value to the sanitary engineering profession. It is important to know that high rates of digestion do obtain in digestion tanks and that, as a consequence, tank volumes can be reduced by increased

utilization of the digestion space by means of better mixing. This is particularly important in installations where the sludge can be disposed of as rapidly as removed from the digester. Where digesters also serve as sludge storage basins, it is advantageous to know the space that must be devoted to the digestion process.

In connection with an experimental pilot digester, such as used by the author, in which tank space was fully utilized by means of adequate mixing, it is interesting to note that the digestion process involved can be mathematically equated. For a digestion tank in which the process is in balance (that is, in which the digestible matter, in the sludge added each hour, less the digestible matter in the sludge removed, equals that digested each hour) the equation is as follows:

$$(1.0 - F + DF) \times (1.0 - R) = DF. \quad (1)$$

in which D is the digester displacement, in hours; R is the digestion rate of the digestible matter, expressed as a decimal fraction per hour; and F is the undigestible matter per unit volume of sludge removed from the digester, expressed as a decimal fraction of that per unit volume of sludge added. This can be reduced to such forms as

$$R = \frac{1.0 - F}{DF - F + 1.0} \quad \ldots\ldots (2a)$$

$$F = \frac{1.0 - R}{DR - R + 1.0} \quad \ldots\ldots (2b)$$

$$D = \frac{RF - R - F + 1.0}{RF} \quad \ldots (2c)$$

which can be used for computing the digestion rate, the undigested fraction, and the displacement period, respectively.

The author's conclusion that for the same degree of digestion two tanks in series require less total volume than one can be demonstrated by means of the Eqs. 2. For example, assume the digestion rate, R, to be the same for one tank alone as in both of two tanks in series, and that it is equal to 0.042, which is the equivalent of the author's digestion index of 100 per cent per day. Also, assume that the digestion must be 95 per cent complete; that is, only 5 per cent of the gas is to be unrecovered. In the case of one tank operating alone the undigested fraction, F, equals 0.05 and from Eq. 2c the displacement period, D, must be 432 hr., or the equivalent of 18 days. For two tanks in series, the value of F would be the same in both, due to the displacement and digestion rate being the same, and would be $\sqrt{0.05}$, or 0.224. From Eq. 2c the displacement for each tank would be 79 hr., or a total of 158 hr. for the two tanks, which would mean a saving of 63 per cent in the total tank volume required.

If the rate of digestion remained unaffected, the total tank volume required could be reduced without limit by increasing the number of stages in the digestion process. However, the author's tests indicated that the process breaks down when the displacement period of the primary digester is reduced to about 3 days and it probably should not be operated at less than 5 days in order to be on the safe side. Therefore, use of more than two stages in digestion does not seem to be practical.

Eq. 2c can be used to determine the effect of mixing by using the equation to compute the percentage of the volume of a heated digester actually utilized by the digestion process. Measurement of the normally unrecovered gas available in a unit volume of sludge removed from a digester, and dividing this by the total gas available in a unit volume of sludge entering the tank, gives the value of the undigested fraction; that is, the value of F. From the pilot digester tests the digestion rate of the digestible matter is probably from 4 to 5 per cent per hour, equivalent to an R of 0.04 to 0.05,

which values, along with that of F, can be used to compute the effective displacement of a tank. For example, the plant tank at Bowery Bay was producing 84 per cent of the available gas, which indicated a value for F of 0.16. Using Eq. 2*c*, the effective displacement was 126 hr., or 5.2 days, if R was 0.04; 100 hr., or 4.2 days, if R was 0.05. The average displacement, based on the total tank volume, was 11.8 days. Thus, for the rates of digestion assumed, between 44 and 36 per cent, respectively, of the tank volume was utilized by the digestion process. The author estimated the effective utilization of the tank volume at 36 per cent based on the relative volume requirements of the pilot digester, and 33 per cent based on the salt displacement test.

For two tanks of the same size operating in series, such as in the pilot digester test, the unrecovered gas available in the sludge removed from the second tank can be computed, assuming the same digestion rate occurs in the second tank as in the first. For example, let A be the rate at which gas is produced in the primary tank; B the rate at which gas is produced in the secondary tank; and C the rate at which available gas is lost in the sludge discharged from the secondary tank. Then, since from Eq. 2*a* the value of F for the two tanks must be the same,

$$\frac{A}{A + B + C} = \frac{B}{B + C}$$

which reduces to the form,

$$C = \frac{B^2}{A - B} \quad \ldots\ldots\ldots (3)$$

Using Eq. 3 the writer computed the rates of loss of available gas in the sludge discharged from the secondary tank in the pilot digester tests. The data on the measured gas production rates of the two tanks were used for this purpose as given in Table II. Adding the rate of gas loss to the sum of the measured rates of gas production in the two tanks gave the rate at which available gas entered the primary digester in the raw sludge. This was done for each period of the test and the digestion indexes computed. The indexes thus obtained agreed closely with the author's for Periods 1 to 8, but were lower for Periods 9 and 10, when there was a definite breakdown occurring in the primary digester. The higher values obtained by the author for the primary digester for Periods 9 and 10 resulted from his assumption that the rate of digestion in the secondary tank continued at about 100 per cent per day regardless of the deteriorated condition in the primary tank and data are given on volatile acid content in the secondary tank which may indicate that he is right. However, his method does indicate a rapid decline in the available gas per pound of volatile solids entering the primary tank in Periods 9 and 10, which is rather difficult to account for. By the writer's method the computed available gas per pound of volatile in the raw sludge remains about the same for Periods 9 and 10 as prior thereto, a condition that would normally be expected.

Mr. Torpey has made a valuable contribution to engineering knowledge in his determination of the rates of digestion of digestible matter in heated digestion tanks. However, it is doubtful if the total volume can ever be fully utilized for the digestion process in plant-size tanks. There is the question of the extent to which effective displacement can be economically increased by means of mixing; that is, relative to the total tank volume. If this should be 50 per cent, then 10 days displacement based on total tank volume would probably be a safe minimum requirement. It is probable, however, that such a tank, due to being half filled with well-digested sludge,

would be more stable than the pilot digester operating at 5 days displacement. However, if the effective displacement of such a plant-size tank of 10 days apparent displacement should be 3 days instead of 5, the process might tend to break down, despite the presence of well-digested sludge occupying 70 per cent of the tank volume, because the buffering effect of this sludge would be very slight, due to it being retained uncirculated in the tank. The extent to which apparent displacements can be reduced in plant-size heated digestion tanks depends on the increased costs involved in producing improved mixing as related to the savings resulting in tank volume required.

EDUCATION A FACTOR IN POLLUTION CONTROL

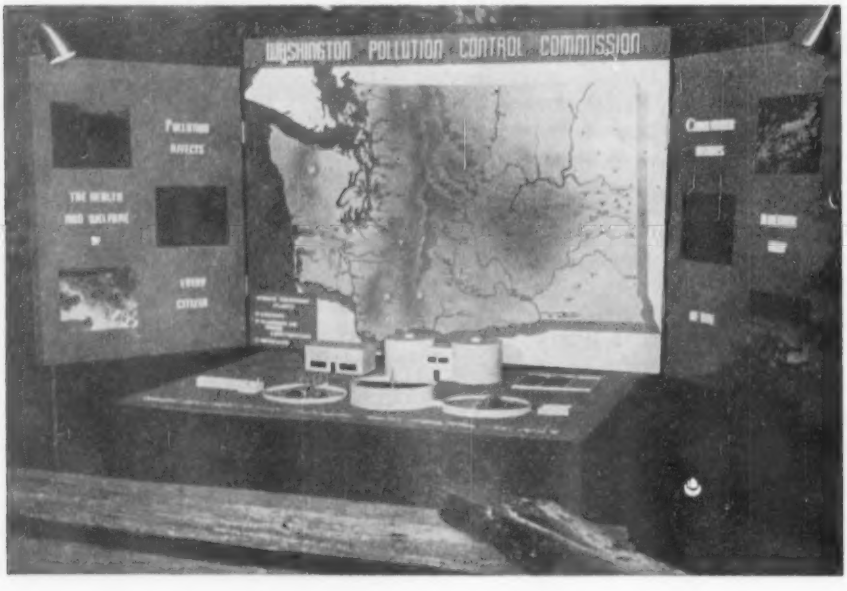
By E. F. Eldridge

Director, Washington Pollution Control Commission, Olympia, Wash.

Education of the public is an important and necessary phase of a pollution control program. To the layman, pollution is undesirable and he is definitely in favor of clean waters; however, for the most part he has little idea of what constitutes a condition of pollution. He hears about sewage treatment and is called upon to pay the cost of the plant for his community. He usually agrees that the treatment of sewage is necessary and seldom complains strenuously about the cost. For this reason he is entitled to a general understanding of the process and its accomplishments.

One method used by the Pollution Control Commission of the State of Washington to inform the people of that state regarding their pollution problem is by an exhibit. This exhibit is shown at fairs and other gatherings throughout the state. In order that it may be effective it is constantly attended by a staff member.

The exhibit contains a working model of a sewage treatment plant. The back board contains a relief map of the state. Holes bored in the map at the location of communities are covered on the back by colored cellophane indicating existing treatment plants, plants under construction, and plants required. Flashing lights back of the board attract attention to the story. On one side panel are three colored transparencies showing polluted waters. The other side panel shows views of clean waters.



FLOW MEASUREMENT IN SEWAGE WORKS *

I. Fundamentals

By Walter H. Brown and George E. Symons

Respectively Project Applications Engineer, Builders-Providence, Inc., Providence, R. I., and Consultant and Technical Editor, Larchmont, N. Y.

This treatise is an organized compilation and basic presentation of the fundamentals of flow measurement in sewage works. The subject is not new; its importance is well known, and many articles have appeared on various phases and aspects of the topic, but the following presentation is an attempt to collect and collate current information in a form that will be useful for reference purposes.

Concept of Quantity

Quantity is an amount of something. In the case of fluids (liquids and gases), quantity is a measure of either volume or mass (weight) of a substance confined or contained in any given structure, vessel, tank, pipe, etc.

Measurement of Quantity

Quantity of a liquid may be determined by weighing it in standard units (pounds, kilograms, or parts thereof) or by measuring the volume occupied using standard units of cubical capacity (cubic feet, gallons, liters, etc.)

Quantity of a gas may be determined by weighing a closed, tared container, but this is impractical for large volumes. Quantity of a gas is preferably determined by measuring the volume occupied in terms of cubical capacity (cubic feet, liters, etc.)

Quantity of both liquids and gases will vary with both temperature and pressure changes. Therefore, it is necessary to set standard conditions to which measurements of quantity can be referred for comparison.

Pressure effects on liquids are negligible; therefore, the standard condition for liquid measurement is 60° F. Both pressure and temperature are important in gas measurement; the standard conditions are 60° F. and 30 in. of barometric pressure. Laboratory observations are sometimes referred to 0° C. (32° F.) and 760 mm. (30 in.) pressure.

Concept of Flow

"Flow" is quantity in movement from one point to another (or past a point) in a specified interval of time. This fundamental idea of flow may be visualized from Figure 1, which shows a pipe connecting two tanks containing a liquid. When the valve is closed, there is no movement of liquid from one tank to the other. Under these conditions the volume of the liquid in the pipe is represented by

$$V = A\,L \qquad (1)$$

in which V is the volume, A is the cross-sectional area, and L is the length of the pipe.

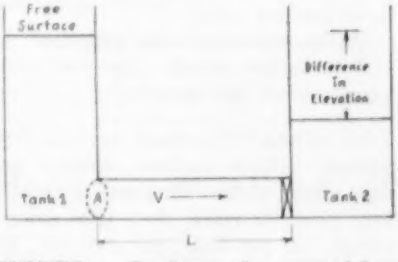


FIGURE 1.—Fundamental concept of flow.

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21-22, 1954.

If the valve is opened, the liquid moves because it is under pressure (head) since the liquid in Tank 1 is higher than the liquid in Tank 2. The quantity moving then becomes the number of times that the length of pipe, L is filled and emptied in a given period of time, T. Since L/T = velocity, it is obvious that for flowing liquids

$$Q = A\,V \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

in which

Q = Volume, in cubic feet per unit time, T;
A = Area, in square feet; and
V = Velocity in feet per unit time, T (usually per second or per minute)

Velocity, or some function of it, therefore is a fundamental factor in the measurement of flow. It is this basic concept on which all flow measuring devices (except gravity scales) are based.

The term "rate of flow" is applied for measurements of quantity in motion for a relatively short unit period of time; for example per second, minute, or hour, and sometimes day. "Total flow" or volume, is the term applied to the total amount of liquid moved during any unit of time, usually referring to a period of a day, month, or year. (Rate of flow is volume per unit time; total volume is average rate multiplied by the time the flow exists.) Rates of flow of liquids are usually expressed in one of these units:

Cubic feet per second (c.f.s.) (or per minute, per hour, etc.)
Gallons per minute (g.p.m.) (or per hour, per day, etc.)
Million gallons per day (m.g.d.)
Pounds per minute (lb. per min.) (or per hour, per day, etc.)

Total volume is expressed in cubic feet, gallons, million gallons, usually per day. Rate of flow for gases is usually expressed in cubic feet per minute (c.f.m.) or per hour, per day, etc., referred to standard conditions.

Reasons for Flow Measurement

In any sewage treatment works there are a number of reasons for measuring flow, as follows:

1. To provide data and information on plant operation. In short, flow measurement gives information on accomplishment (or lack of it) and indicates to an operator, whether or not a plant is functioning properly.

Data on total volume treated in a plant, or handled in sewers, in a day, week, or year, will serve for comparison purposes and help to chart trends and conditions necessary for future planning and changes or additions needed in the system. Data on rate of operation and total volume handled by individual operating units, aid in the proper operation and maintenance of those units; for example, settling tanks, trickling filters, activated sludge units, digestion tanks, etc.

2. To provide information on operating efficiency, particularly unit operations, such as pumping, sedimentation, oxidation, disinfection, and digestion.

3. To provide control of unit operations such as sewage flow, pump operations, dosage rates in trickling filters, aeration and return sludge in activated sludge, sludge loading on digesters, digester heating, sludge disposal operations (particularly where elutriation and chemical dewatering and incineration are practiced), and in chemical feeding.

4. To ascertain quantity of sewage received from outlying communities or from industrial establishments, particularly where charges for treatment are made against the outlying community or the industries.

5. To determine costs of operation, both over-all and unit operations, since practically all costs are based on volume handled, usually calculated per million gallons.

6. To provide records of performance. Such records enable officials responsible for plant operation to pre-

pare reports to the public and to state health departments on accomplishments of the plant and efficiency of operation. Records are also an aid in the case of lawsuits resulting from alleged pollution or nuisance conditions.

Devices for Flow Measurement

Several devices are available for measuring flow rates.

Gravimetric Scales

A scale can determine the weight of fluid confined in relatively small containers, and thus give a measure of total quantity; but it is generally impractical to weigh large quantities and such a system can be applied only to batch movement.

Measurement of flow rates of liquids on scales is possible only in loss-of-weight feeders or meters, which continually weigh, indicate, and record the decrease in weight of a container of liquid. Tank car lots are the largest feasible size of container for this purpose.

Measurement of flow rates of solids is possible with a conveyor-type scale (weightometer) where the weight of solid on a moving belt is determined. This device is used in weighing sludge from vacuum filters.

Fill-and-Draw Devices

The total quantity of a liquid (or a gas confined by a liquid) can be determined if the liquid enters and leaves a vessel of known cubical content. The change in liquid level in the vessel or tank is a measure of liquid volume contained in the vessel. This method has the limitation that the change in level must be due solely to the liquid entering or leaving the tank; input and output cannot take place at the same time.

Fill-and-draw devices are useful for measuring liquids in reservoirs, storage tanks, digestion tanks, etc., and thus for determining the total volume of the liquid going in or out. Rate of flow can be determined by such devices only by timing the linear travel of the surface of the liquid.

The *tipping bucket* for measuring digested sludge, etc., is the simplest form of fill-and-draw device; a counter attached to the motion of the bucket will serve as a means of calculating the total quantity of flow. Rate of flow is seldom determined by a tipping bucket, but could be done by timing the number of operations over a specified period.

Pumps

If liquids are pumped, the number of repeat cycles of operation of the pump can be used as a measure of the total flow and the rate of these operations can be used as a measure of rate of flow.

Controlled volume reciprocating pumps give a constant output for each cycle of operation; but centrifugal pumps, if used for measuring purposes, must be calibrated as to discharge for each speed of operation, suction lift, and discharge pressure.

Constant Differential Meters

The rotameter is a rate-of-flow indicator for liquids and gases. It consists of a tapered tube, smaller at the bottom than at the top, and a movable element, called the "float," which rises in the tube as the flow through the tube increases. The difference in pressure below and above the float remains constant and the position of the element gives a fairly accurate measure of instantaneous rate of flow. This device is not used for large flows.

Head-Area Meters

A head-area meter is a flow measuring device used only for open channel flow or flow in partially filled pipes. It operates on the principle that a con-

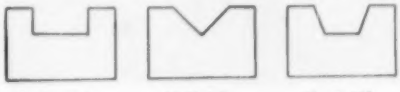


FIGURE 2.—Types of weirs.

FIGURE 3.—Parshall flume installation.

striction or controlled barrier in the flow channel will back up the liquid (to force the liquid past the barrier) creating a higher level or head than the level below the barrier. This head or elevation of the liquid above the barrier is a function of the velocity of flow and therefore of volume flowing through a known constriction per unit time. For proper operation, the level of liquid below the barrier must be lower than it is above.

FIGURE 4.—Open flow nozzle installation.

Weirs are barriers or dams of controlled and predetermined cross-section, the flow characteristics of which have been determined and formulated. Common weirs (V-notch, rectangular, and Cipolletti) are shown in Figure 2. Another type is the Sutro or proportioning weir.

Measuring flumes are constricted channels of predetermined dimensions. There are two types: the Venturi flume, seldom used, and the widely known Parshall flume (Figure 3).

An open flow nozzle (Figure 4) consists of a constriction at the end of a pipe, flowing partially full, from which the flow drops without interference to a lower level.

Functional Meters

Functional meters are mechanical devices which measure some function of the volume or mass in movement, and by means of other mechanical devices convert this measurement into units of rate of flow or total quantity of flow. (Note: Displacement meters, like the common household water meter, are essentially "closed tipping buckets" and operate on the fill-and-draw principle.)

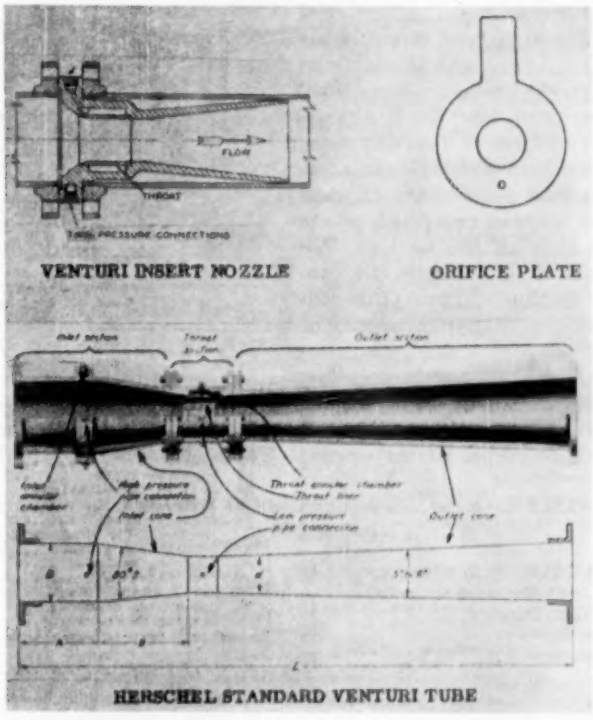


FIGURE 5.—Types of differential head producers.

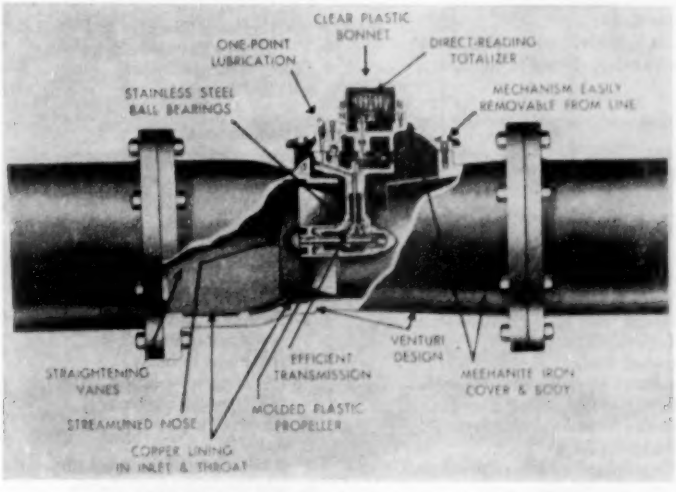


FIGURE 6.—Cutaway view of velocity meter.

There are several types of functional meters—differential head meter, velocity meter, Pitot tube, and Massometer. The first three all measure some function of velocity of flow; the last measures an inertia force of a moving mass.

Differential head meters, as the name implies, produce a difference in pressure (head) between two points as the fluid flows through the device. The essential part of these meters is a constriction in the line of flow. This constriction causes a change in velocity of flow accompanied by a change in pressure (head). The change in pressure, or differential head, between the two points is proportional to the square of the flow. Three types of differential head meters (Venturi tube, insert nozzle, and orifice) are shown in Figure 5. There are other types of differential

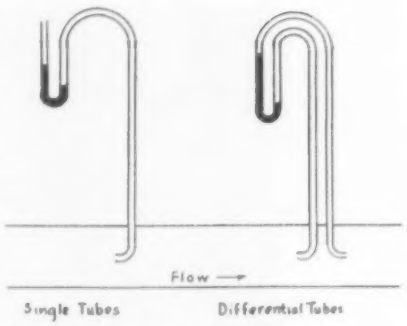


FIGURE 7.—Single and differential type Pitot tubes.

TABLE I.—Meter Locations for Complete Metering in Sewage Works

Sewers

1. Main sewers tributary to interceptors
2. Tributary from outside municipality
3. Tributary from industry
4. Lift station discharge
5. Sampling stations

Pumping

1. Running-time meters

Primary Treatment

1. Influent to plant
2. By-pass lines
3. Influent to individual settling tanks
4. Settled sludge, drawn or pumped

Disinfection

1. Chlorine
2. Water for chlorination

Secondary Treatment

A.—Trickling filters:
   1. Influent to each filter dosing tanks (counters)
   2. Sludge from final clarifier
   3. Recirculation

B.—Activated sludge:
   1. Influent to each aeration tank
   2. Return sludge to each tank
   3. Sludge from final clarifier
   4. Sludge to waste
   5. Air volume to each aeration unit
   6. Total air volume
   7. Ratio of air to sewage
   8. Ratio of return sludge to sewage

Sludge Digestion

1. Raw sludge added
2. Digested sludge drawn
3. Supernantant liquor drawn
4. Gas volume produced
5. Heating-water flow
6. Recirculation through heat exchanger
7. Gas burned for sludge heating

Sludge Disposal

1. Sludge volume handled
2. Sludge dewatering:
   (a) Elutriation water
   (b) Elutriated sludge
   (c) Ratio of sludge to elutriation water
   (d) Dewaterated sludge cake
   (e) Filtrate liquor
   (f) Chemicals

Miscellaneous

1. Plant water
2. Gas used
3. Electricity
4. Fuel oil
5. Potable water

Measurements Other Than Flow

1. Temperature:
   (a) Atmosphere
   (b) Plant influent
   (c) Digester heating water
   (d) Digester contents
2. Barometric pressure
3. Rainfall
4. Wind direction and velocity
5. Gas concentration alarms
6. Pressure in pipelines
7. Tank levels

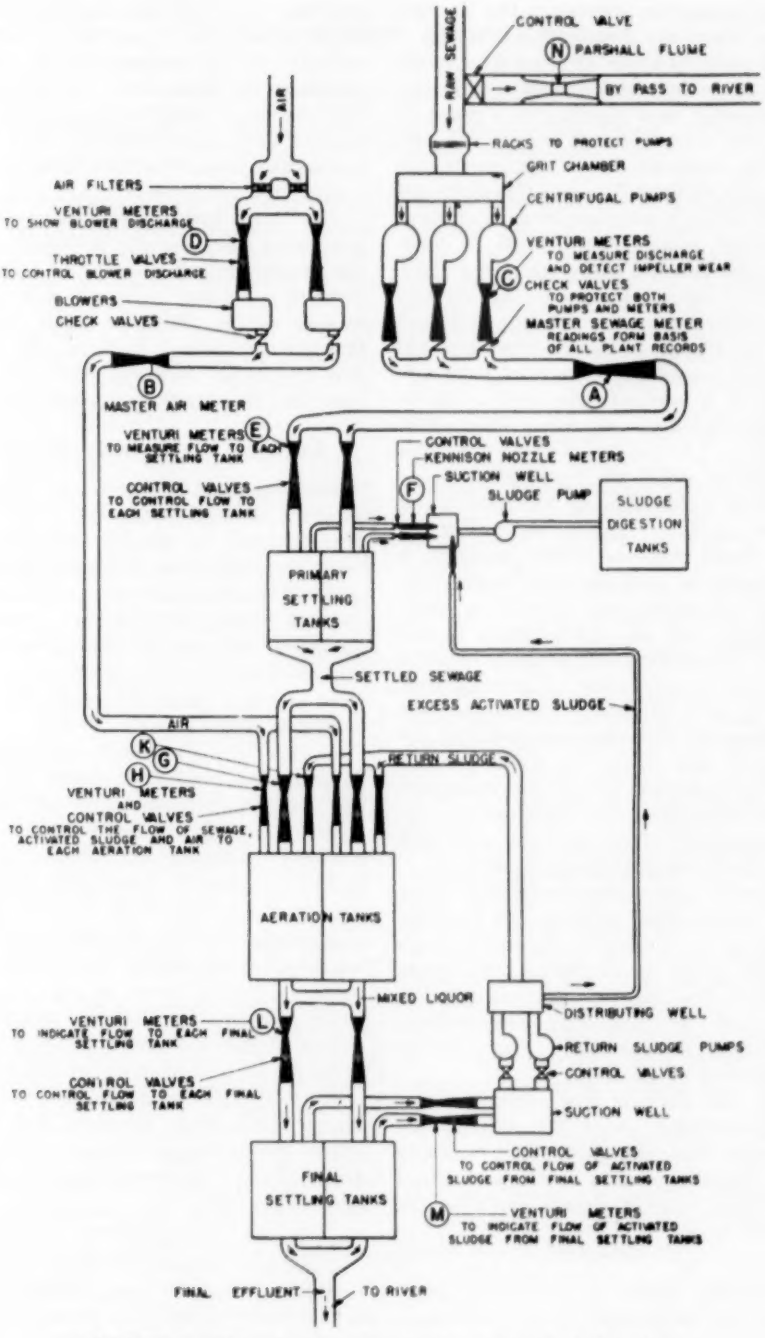


FIGURE 8.—Meter location diagram for activated sludge plant.

head producers, similar to the Venturi tube; these are discussed in Part II.

A *velocity meter* (Figure 6) consists of a device by which a vane or propeller is inserted in a pipeline at a point of definite cross-sectional area. This propeller turns in direct relation to the velocity of fluid flow and therefore can be used as a measure of rate of flow. Velocity meters, when used in open channel flow are called current meters.

Pitot tubes (Figure 7) are devices for determining the velocity of liquid flow at a point of known cross-sectional area of a conduit. The Pitot tube consists of a vertical tube with a tip at right angles, the tip being inserted in an open flow and faced upstream. The height to which the liquid rises in the tube is a function of the velocity of flow and, hence, rate of flow. For use in closed systems under pressure, a variation is used wherein the tube tip faces upstream and there is a static pressure tap at right angles to the flow. The differential pressure between the two is a function of velocity and, hence, rate of flow. To increase the differential and improve reading accuracy, two tubes are used, one tip facing upstream and one downstream. The differential thus produced is approximately twice that obtained with the single tip and static pressure tap.

Inertial flow meters are devices which do not measure volume, but measure mass in movement by determining an inertia force developed by the flowing mass. The measurement is not influenced by viscosity, temperature, pressure, compressibility, or non-homogeneity of the fluid.

In the Coriolis flow meter, an impeller rotates about the axis of the flowing fluid; that is, at right angles to the direction of fluid flow. As the fluid particles enter the meter and meet the rotating vanes of the impeller, their axial velocity is converted to radial velocity, which increases as the fluid travels to the outer rim of the impeller. This increase in radial velocity is known as the "Coriolis acceleration" and is a measurable force directly related to the mass of the fluid flow.

The Gyro flow meter measures the precession effect (as the wobbling of a top or gyroscope) of a liquid passing through a circular pipe, which rotates as a gyroscope, while the liquid passes through the pipe. Both of the last two devices are new and have not yet been used in sewage flow measurement.

Location of Metering Points

The location of metering devices within a sewage works, including the sewer system, is usually dictated by three considerations—factors of design, personal preferences of the designer, and information desired for operation purposes. It is seldom a matter of cost, inasmuch as the cost of metering equipment is but a small percentage of the total cost of the plant.

In view of the relatively low cost of metering equipment, complete metering should be considered in all of the larger plants and in many small ones. Complete metering will assure availability of complete information on all phases of operation and make it possible to know the performance of the whole plant as well as its component parts. Table I is an outline of the meter locations for complete metering. Figure 8 shows a meter location diagram for an activated sludge plant.

[Part II, to be published in the March 1955 issue, presents and discusses the principal devices available and used for flow measurement in sewage works.—Ed.]

EVALUATION OF ODORS

By C. W. Beardsley and N. J. Krotinger

Director and Materials Testing Engineering Assistant, respectively, Bureau of Standards, Department of Public Works, Los Angeles, Calif.

Of the seven or eight senses possessed by the human race, only two depend upon the chemical properties of matter. Taste and smell are responses to the chemical structure of molecules contacting the sensory surfaces. All of the other senses are physical in nature and are responses to such stimuli as light, heat, sound, and mechanical motion.

Instrumental aids have been developed for the physical senses. Many optical devices have been used to supplement the eye. It is possible to determine and record the wavelength, frequency, intensity, and distribution patterns of light with great precision. In some cases the capacity of the eye to evaluate properties of light has been increased 1,000,000-fold.

A similar extension of range occurred for the other physical senses. Heat, sound, temperature, and motion are subject to measurements of the most exquisite refinement.

No apparatus has been devised to replace the most primitive of the senses, the sense of smell.

Odor Perception an Individual Characteristic

Instrumental measurements of odor are not possible, because the perception of odor is determined not only by the chemical structure of the molecules contacting the olfactory surfaces, but also by the genetic make-up of the perceiving individual. Every person has his own private perception of odor which is as intimate and individually characteristic of him as the chemical make-up of the chromosomes in his cells.

Although precise determinations of the intensity and character of odors are not possible, it is often desirable to estimate the potential annoyance of an odorous gas to the general public. Large sums are expended for the control or amelioration of unpleasant odors. When counteraction or masking, absorption or adsorption are employed, complete elimination of the odor is seldom achieved. In such cases a determination of the effectiveness of the process is needed. When catalytic oxidation is employed, malodorous residues of combustion are sometimes present in the effluent gases, and it is desirable to compare the burned and unburned gases.

In all investigative work numerous estimates and comparisons of odor levels must be made. In estimating odor intensity and character, it is desirable to obtain a consensus of several observers. In the case of certain substances little agreement will be found among different individuals as to the quality of the odors. If a panel of observers is asked their opinion of the odor of freesias, ratings of pleasant, unpleasant, and odorless will be obtained and opinion will be about equally divided. For most malodorus substances, however, the ratings obtained from a panel are likely to be similar with an occasional dissent from a single individual. Such a consensus may be considered to represent a normal reaction to the odor in question.

Precautions in Making Odor Estimates

When obtaining an odor estimation from an observer the following precautions should be taken:

1. The observer should not be exposed to the odor prior to the time when the rating is made.

2. The gas temperature should be at the ambient temperature.

3. The exposure to the odor should be brief (not more than one or two seconds).

4. At the instant when the observation is made the gas should be present in a sufficient quantity to fill both nostrils.

5. The gas should not be blown rapidly against the olfactory surfaces.

6. The observer should hear no comments or suggestions before his rating is recorded.

7. The observation should be recorded immediately after it is made.

The reasons for most of the precautions are obvious. Nearly everyone is aware of the rapid accommodation of the olfactory sense to odors, which makes it imperative that the observation be brief. The profound effect of the temperature and velocity of the gas on the olfactory sensation are not so generally appreciated. It is impossible to estimate the odor of a hot gas or to properly evaluate the odor of a rapidly moving gas stream (such as the discharge from a vent pipe or duct). The olfactory sensation is profoundly modified by changes in the velocity and temperature of the odoriferous gas.

Los Angeles Studies

Various methods of eliminating or ameliorating sewer odors have been under study by the Department of Public Works of the City of Los Angeles for several years. All of the usual methods of odor reduction, including absorption, adsorption, counteraction, and catalytic oxidation, have been tried. Each process tested has made necessary repeated evaluations of the odor, both with and without treatment.

A convenient procedure for obtaining ratings from a panel of observers has been developed by the Los Angeles City Bureau of Standards. Polyethylene bags 10 in. by 10 in. by 30 in. in size and costing less than $0.10 each are used. These bags (Figure 1) are filled with about 40 l. of the gas that is to be evaluated. The open end of the bag is closed by wrapping and tying it tightly around an annular

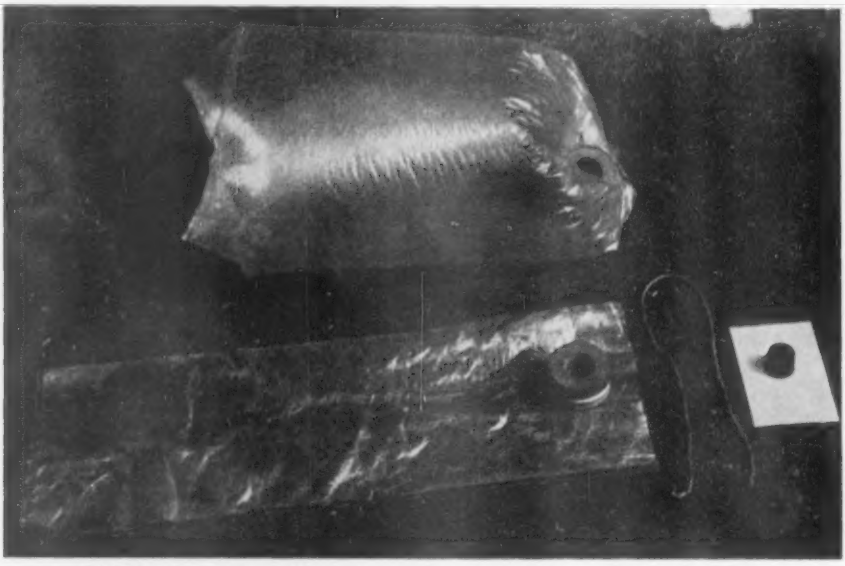


FIGURE 1.—Polyethylene odor sampling bag before and after inflation.

FIGURE 2.—Evaluation of odor treatment by several observers away from odor source to eliminate olfactory accommodation.

wooden closure member having an orifice with a rubber stopper. The wooden member should be heated to remove any characteristic odors before using it initially.

At sewer ventilating stations there is enough pressure to fill these bags at any convenient opening after the blower. At sewer manholes a hand-operated blower (1) is used to fill the bag. To evaluate combustion processes, a pipe is inserted into the outlet side. The hot gases are cooled by water-soaked rags tied to the pipe. The other end of the pipe is inserted into the wooden closure member. In some cases, where the pressure is too low, the pipe is led to the inlet side of the hand-operated blower and the bags are easily filled.

Threshold concentration of odors can be evaluated by placing the filled bag in a wooden box more than 30 in. high, open at the top, and with one side movable. A definite volume of the odor-bearing gas is pressed out, and the bag re-inflated with the hand-operated blower using fresh air as the diluent. This process is repeated until the odor is just perceptible.

Oxidation of odors has not seriously affected the determinations. An odor, very irritating to mucous membranes, obtained after a high-temperature combustion process will still exhibit irritating properties after holding the gas several hours in the plastic bags.

Adsorption of the odors or masking agents upon the walls of the bags has not been a problem. A single inflation with fresh air after expelling the odor under test is sufficient to remove almost all traces of very strong odors.

It is possible to obtain a rating by six or more observers (Figure 2) from a single bag full of gas. The bag is held close to the observer's face, the rubber stopper is briefly removed, and about 1 l. of the gas is expelled. The rater is thus enabled to obtain a brief impression of the undiluted odor.

This method of securing a rating has several advantages for evaluating sewer odors and the effects of odor treatment, as follows:

1. The rating need not be made at the source of the odor. Sewer odors may be transported in the bag more than 20 mi. with only slight decrease in strength. This makes it possible to obtain ratings from persons who are not available at the place of odor treatment.

2. The rating can be made by observers who have not previously been in contact with the odor. The atmos-

phere at a sewer location is generally tainted with the odor under test. When an observer is taken to the site of an odor treatment operation, some degree of accommodation is likely to occur before a rating can be made.

3. The untreated gas can be stored for ready comparison with the odor after treatment. The observer is able to form a more reliable opinion of the effect of treatment if the end product is immediately compared with the original odor.

4. When gases discharged from oxidation processes are too hot for accurate evaluation, they can be cooled to ambient temperatures before testing.

5. Threshold concentration can be determined by expelling a fixed amount of the gas and re-inflating with fresh air.

6. The equipment is inexpensive and portable.

Reference

1. Krotinger, N. J., "Laboratory Organization and Techniques for Large-Scale Sewage and Industrial Waste Testing." THIS JOURNAL, **24**, 10, 1266 (Oct., 1952).

EFFECT OF SOILS ON ASBESTOS-CEMENT PIPE

Detailed information regarding the effect of soil exposure on the properties of asbestos-cement pipe has resulted from field studies recently completed by the National Bureau of Standards as part of a long-range program to determine the effects of various soils on materials for underground construction. Representative specimens were exposed to a wide variety of soil types for periods up to 13 years and, upon removal, the physical and mechanical properties of the pipe specimens were carefully investigated.[1] The data thus obtained provide an over-all picture of the rate and extent of alteration of this type of pipe in the soils studied.

The exposure studies included two varieties of asbestos-cement pipe specimens, one 4 in., the other 6 in. in diameter, designed to withstand a pressure of 150 lb. per sq. in. (class 150 pipe). Both sizes of pipe were fabricated in essentially the same manner.

Six-inch specimens were removed from the 15 exposure sites after periods of 2, 4, 9, 11, and 13 years. Four-inch specimens were taken up at the end of 2, 7, 9, 11, and 13 years. After removal the specimens were tested for hydrostatic bursting strength, crushing strength, water absorption, apparent specific gravity, and condition of the surface of the specimens. Representative specimens of unexposed pipe of both types were also subjected to the same tests, to supply reference data in determining the effects of the various soils and periods of exposure on the pipe materials.

In general, the data show an increase in strength during the early periods of exposure followed by a decrease in strength during the latter periods. The increased strength, which is generally accompanied by a decrease in water absorption, is associated with a curing process that continues for several years during exposure to the soil. After the completion of the curing process, the specimens were subject to weathering, as manifested by loss in strength, decrease in apparent specific gravity, increased absorption of water, and superficial softening.

The averages of the strength and water-absorption measurements indicated that the curing period was 2 to 4 years in the 6-in. pipe, as compared with approximately 7 years in the 4-in. pipe. This longer curing period may be due not only to different initial curing processes, but also to differences in dimensions, composition, and method of fabrication. Weathering also proceeded more rapidly in the larger than in the smaller pipe.

The rate and extent of alteration of the specimens were affected considerably by the nature of the soil conditions to which they were exposed. For example, weathering was accelerated by both organic and inorganic acidity. Since the decomposition of organic matter provides a large amount of carbonic acid to the ground water and so increases its activity, relatively greater losses in strength of portland cement would be expected in soils high in organic matter.

The average tensile strength of the 6-in. pipe after 13 years exposure was of the same order of magnitude as that of the unexposed pipe, and that of the 4-in. pipe was still higher. Even under the most adverse conditions to which the specimens were exposed, the bursting and crushing strengths of all the samples after exposure were higher than the requirements of the Federal specifications for asbestos-cement pipe.

[1] Romanoff, M., and Denison, I. A., "The Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe." *Corrosion*, **10**, 169 (1954).

EFFECT OF DRIED SEWAGE SLUDGE ON NITRIFICATION IN SOIL *

By James E. Fuller and G. W. Jourdian

Department of Bacteriology, University of Massachusetts, Amherst, Mass.

The possibility of utilizing sewage sludge as fertilizer has been for some years a matter of interest to both agriculturists and sewage treatment plant operators: to the former, as a source of organic fertilizer for soils in lieu of increasingly inadequate supplies of barnyard manure; to the latter, as a means of disposing of accumulations of sludge. The subject has been reviewed at some length in the Federation's Manual of Practice No. 2 (1).

If sludge is applied to soil, two factors must be considered. The first is the hygienic aspect of the use of sludge; that is, the possibility that enteric infectious diseases may be so disseminated. This subject has been discussed, for all types of sludge, in Manual of Practice No. 2. Wolman (2) summed up the subject by stating that sewage sludge may be used as a garden fertilizer without detriment to human health if the sludge is held in a digestion tank for not less than ten days before it is put on the field, and that it must be applied before the crop is planted.

The second concern is the fertilizer value of sludge and its effect on soil. This topic is reviewed also in Manual of Practice No. 2. In several cities sludge is processed and mineral constituents are added to produce a marketable fertilizer. Milorganite is an example of this kind of treatment. Van Kleeck (3) has presented an interesting pictorial report of the results achieved by using sludge as a fertilizer in a landscaping project. He also lists several of his bulletins and journal publications on the subject.

The present study was concerned with digested sludge from a primary treatment plant with separate sludge digestion. Fuller and Litsky (4) studied the survival of *Escherichia coli* in the drying and dried sludge and found that the organism disappeared fairly rapidly and was replaced by nonfecal coliform types. It seemed reasonable to conclude that pathogenic enteric bacteria would not survive in the sludge longer than the *E. coli*.

The purpose of the present study was to contribute more information on the desirability of this type of sludge as a source of organic fertilizer. The particular objective was to determine the effect, if any, of the sludge on nitrification in soil. No work has come to the authors' attention on this aspect of sludge utilization.

In the process of sludge digestion at the disposal plant, the organic matter that is readily digestible disappears in a few days, with the result that the digested sludge consists largely of residual organic matter that is quite resistant to further digestion. It is obvious that any organic matter added to soil will be attacked and digested eventually by soil microorganisms. Since such digestion will proceed slowly, it seemed possible that the microorganisms engaged in the process might use some of the soil nitrate as a readily available source of nitrogen and thus deplete the nitrate content of the soil. The study was undertaken to determine whether or not this would happen. Although the sludge contained about 1.5 per cent nitrogen, it was not expected that this would add materially to the nitrate content of the soil. If some of this nitrogen were nitrified, such nitrate

* Contribution No. 953, Massachusetts Agricultural Experiment Station.

could be considered in the nature of a "bonus." In other words, the authors were interested principally in the use of the sludge as an organic conditioner.

The general plan of the experimental work was to determine nitrification of the soil's own nitrogen, as a control, and nitrification of nitrogenous substances added to the soil. These nitrification studies were made in soil with and without added sludge.

Experimental Materials

With the exception of one clay soil, the soils employed in these experiments were sandy loams characteristic of the Connecticut Valley in Massachusetts. Soil was collected, air-dried in the laboratory, screened through a 40-mesh screen, and stored in a dry place until used.

The sewage sludge was obtained from the local sewage treatment plant, a primary plant with separate sludge digestion. After digestion, the sludge is filtered on a sand filter and dried. Dried sludge was taken to the laboratory where it was pulverized, screened through a 40-mesh screen, and stored in a dry place until used.

The procedure for setting up a study of nitrification in soil was that described by Waksman (5). Three sources of nitrogen were employed: ammonium sulfate, cottonseed meal, and dried blood. Ammonium sulfate was selected to give information concerning the direct oxidation of ammonia to nitrate. Production of nitrate from the cottonseed meal and the dried blood involves the whole process of digestion of protein materials to ammonia and the consequent oxidation of the ammonia to nitrate. Cottonseed meal and dried blood were selected to provide both plant and animal proteins.

Experimental Procedure

The water-holding capacity of the soil was determined; then, 100-g. portions were put into glass jars. The various treatment categories were set up according to the following pattern:

1. Soil, without addition, for control.
2. Soil with ammonium sulfate, to give 30 mg. N per jar.
3. Soil with 1 g. cottonseed meal per jar.
4. Soil with 0.25 g. dried blood per jar.

With each of these categories, equal numbers of jars were prepared with and without the dried sludge, which was added at the rate of 1 g. per jar.

Preliminary experiments had shown that some control of acidity was needed, so 0.25 g. of calcium carbonate was added to each jar (5).

Cottonseed meal, dried blood, sludge, and calcium carbonate were added directly to the soil and mixed thoroughly. Ammonium sulfate was dissolved in water in a proportion that would give the desired amount of nitrogen per jar when the water was added to the soil. The moisture in each jar was made up to one-half of the water-holding capacity of the soil.

All samples were set up in triplicate for each category, and all experiments were repeated at least three times.

When the samples had been prepared, the jars were weighed. The weight was rechecked at least twice each week, and water was added as needed to make up loss by evaporation. The jars were covered lightly to control evaporation somewhat, and were stored in a dark place at room temperature (about 75° F.) Storage periods were one, two, and three months.

After the samples had been stored for desired lengths of time, the content of each jar was put into a measured amount of water, shaken in a mechanical shaker, then filtered. Nitrate determinations on aliquots of the filtrates were made by the phenoldisulfonic acid method of Snell and Snell (6). An electrophotometer was employed for the readings. All values were calculated as p.p.m. of nitrogen.

TABLE I.—Nitrate Nitrogen[1] from Ammonium Sulfate[2] in Sandy Loam Soil, with and without Sludge

Category	Sample 1			Sample 2		
	Low	High	Mean	Low	High	Mean
Soil (control)	—	—	1.00	—	—	1.00
Soil with sludge	1.20	1.24	1.22	1.11	1.15	1.13
Soil with ammonium sulfate	5.45	5.80	5.55	4.15	5.00	4.80
Soil with ammonium sulfate and sludge	6.45	6.66	6.55	4.67	5.32	5.10

[1] Values expressed as ratios to control.
[2] 30 mg. N per 100 g. soil.

Experimental Results

All data were calculated as ratios based on the controls; that is, on nitrification of the soil's own nitrogen. This calculation was necessary for comparison of results obtained with different lots of soil because the soil samples had been collected from plots with varied previous treatments of fertilizer and lime and had been planted with a variety of crops. Thus, when data for different soil samples were compared, the control values differed considerably, and so did the nitrification of the added nitrogenous materials. Since the purpose of the investigation was to learn whether or not the added sludge affected the nitrate content of the soil, it seemed best to consider each soil as an entity and to use the control as a basis of calculation. Hence, the ratio system seemed to be the only way in which the values for the different soils could be compared with any accuracy.

The data shown in the accompanying tables were results from jars that had been stored for one month. This conforms to the procedure outlined by Waksman (5). Results from jars stored for two months showed slightly larger amounts of nitrate nitrogen than were obtained for one month, but the same trends appeared. In jars stored for three months, the results were more divergent than were those for one and two months. Since the data for one month of storage were representative, they were selected for presentation (Tables I, II, and III). For all categories, the combinations were prepared with and without sludge. All were prepared in triplicate.

An additional experiment was performed with a heavy clay soil, the results of which are shown in Table IV. Since, in this experiment, the jars were

TABLE II.—Nitrate Nitrogen[1] from Cottonseed Meal[2] in Sandy Loam Soil, with and without Sludge

Category	Sample 1			Sample 2		
	Low	High	Mean	Low	High	Mean
Soil (control)	—	—	1.00	—	—	1.00
Soil with sludge	1.16	1.25	1.22	1.47	1.55	1.50
Soil with cottonseed meal	8.25	8.95	8.80	6.63	6.80	6.70
Soil with cottonseed meal and sludge	8.25	9.60	9.10	7.00	7.25	7.18

[1] Values expressed as ratios to control.
[2] 1g. per 100 g. soil.

TABLE III.—Nitrate Nitrogen[1] from Dried Blood[2] in Sandy Loam Soil, with and without Sludge

Category	Sample 1			Sample 2		
	Low	High	Mean	Low	High	Mean
Soil (control)	—	—	1.00	—	—	1.00
Soil with sludge	1.15	1.18	1.17	1.18	1.20	1.19
Soil with dried blood	3.67	3.84	3.80	3.14	3.40	3.31
Soil with dried blood and sludge	4.00	4.31	4.16	3.40	3.53	3.49

[1] Values expressed as ratios to control.
[2] 0.25 g. per 100 g. soil.

prepared for all categories at the same time, they were prepared only in duplicate because of the time required to make the terminal nitrate determinations.

Discussion

Throughout the series of experiments the general trend of results was the same in that the soil combinations containing dried sludge gave nitrate results equal to, or greater than, those obtained from the analogous combinations without sludge. This would indicate that the sludge at least did not deplete the nitrate content of the soil. On the contrary, in most instances, the sludge appeared to contribute some nitrate to the soil and, in view of the objective of this investigation, the nitrate so contributed may be regarded as a "bonus." The results from the clay soil are included in this summary.

TABLE IV.—Nitrate Nitrogen[1] from Ammonium Sulfate,[2] Cottonseed Meal,[3] and Dried Blood,[4] in Clay Soil, with and without Sludge

Category	Low	High	Mean
Soil (control)	—	—	1.00
Soil with sludge	1.12	1.12	1.12
Soil with ammonium sulfate	5.16	5.50	5.33
Soil with ammonium sulfate and sludge	5.66	5.66	5.66
Soil with cottonseed meal	6.32	6.50	6.42
Soil with cottonseed meal and sludge	6.66	6.66	6.66
Soil with dried blood	4.34	4.50	4.40
Soil with dried blood and sludge	4.34	4.50	4.40

[1] Values expressed as ratios to control.
[2] 30 mg. N per 100 g. soil.
[3] 1 g. per 100 g. soil.
[4] 0.25 g. per 100 g. soil.

Nitrate values from combinations containing dried blood appear, from the tables, to have lower ratios to the controls than do the values from combinations containing cottonseed meal. That is because preliminary experiments had shown that 1 g. of dried blood gave so much nitrate that the filtrate required substantial dilution, so only 0.25 g. of dried blood was used per 100 g. of soil. The use of a smaller quantity of dried blood was preferred to a higher dilution of the filtrate.

It must not be inferred that all results came out so perfectly that no discrepancies appeared. However, there were instances in which the discrepancies from a single combination without sludge were as great as any between analogous combinations with and without sludge. On the whole, very satisfactory agreement was obtained among the triplicate jars of the various combinations; and the experiments were repeated enough times, and with soil from different sources, so that it was permissible to discard occasional discrepant data.

The sludge employed in this investigation contained no industrial wastes. In highly industrialized communities the presence of industrial wastes in sludge would be almost certain, and such wastes might well be detrimental

if added to soil. This problem would require separate study and was not within the scope of the present investigation.

Summary

The effect of dried sewage sludge on nitrification in soil has been studied in the following combinations, with and without added sludge:

1. Soil, for control.
2. Soil with ammonium sulfate.
3. Soil with cottonseed meal.
4. Soil with dried blood.

Results indicated that the combinations with added sludge gave nitrate values as high as, and usually greater than, those obtained from analogous combinations without added sludge.

The data obtained from this investigation indicate that the use of dried sewage sludge as a fertilizer will not deplete the nitrate content of soil, but may even add some nitrate to the soil.

The sludge employed in this investigation contained no industrial wastes. The desirability of using sludge containing such wastes would require separate study.

References

1. "Utilization of Sewage Sludge as Fertilizer." Manual of Practice No. 2, Federation of Sewage Works Assns., Champaign, Ill. (1946).
2. Wolman, A., "Hygienic Aspects of the Use of Sewage Sludge as a Fertilizer." *Eng. News-Rec.*, **92**, 198 (1924).
3. Van Kleeck, L. W., "This Is the Lot that Sludge Nourished." *Water and Sew. Works*, **99**, 244 (1952).
4. Fuller, J. E., and Litsky, W., "*Escherichia coli* in Digested Sludge." THIS JOURNAL, **22**, 7, 853 (July, 1950).
5. Waksman, S. A., "Microbiological Analysis of Soil as an Index of Soil Fertility. V. Methods for the Study of Nitrification." *Soil Sci.*, **15**, 241 (1923).
6. Snell, F. D., and Snell, C. T., "Colorimetric Methods of Analysis." 3rd Ed., Vol. II. D. Van Nostrand Co., Inc., New York, N. Y. (1951).

GRADUATE ASSISTANTSHIPS AVAILABLE

The State College of Washington has announced the availability of several graduate assistantships leading toward a Master of Science degree in sanitary engineering. The appointments involve half-time research during the academic year, with full-time research during the summer.

Further information on these openings may be secured by writing Professor Emmett B. Moore, Chairman, Department of Civil Engineering, State College of Washington, Pullman, Wash.

EFFECT OF BACTERIAL FLORA ON DEOXYGENATION

By William L. Tidwell and J. H. Sorrels

Assistant Research Bacteriologist and Research Engineer, respectively, Texas Engineering Experiment Station, Texas A. & M. College System, College Station, Tex.

The test for biochemical oxygen demand (B.O.D.) is the most common and probably the most important laboratory test in sanitary analyses to determine the strength of sewage or a highly polluted effluent. The quantity of oxygen required for the complete stabilization of a sewage may be taken as a measure of its content of organic matter. The value, generally reported as the B.O.D., is the amount of oxygen (in parts per million) absorbed in a specific number of days, usually five.

It is well recognized that this 5-day B.O.D. is dependent not only upon the organic matter present, but also upon the complex microbiological system existing in the sewage. It has been shown, for example, that the protozoa in a sewage dilution increase as oxidation proceeds, decreasing the number of bacteria available for the oxidation of the sewage (1). This leads to a B.O.D. lower than expected when a substrate of known composition is used. This variable biota undoubtedly is responsible also for the divergent results which have been obtained when given samples of sewage were analyzed in different laboratories and when sewages from different sources were used as inocula in determining the B.O.D. of such standard solutions as glucose and peptone (2).

Zehnpfennig and Nichols (3) have discussed this effect of a varying biota extensively in describing their studies on the oxidation of substrates by using protozoa-free bacterial cultures as inocula. In their initial studies they used single species of bacteria as inocula, but found this an impractical procedure. In their later studies they filtered sewage to remove protozoa and incubated this filtrate in autoclaved sewage, obtaining a bacterial inoculum which gave better reproducibility than did the standard 5-day B.O.D. test.

An independent investigation in the Texas Engineering Experiment Station's laboratory using single species of bacteria as inocula confirmed the conclusions of Zehnpfennig and Nichols as to the impracticality of this procedure. The cultures used in these experiments were *Escherichia coli, Pseudomonas aeruginosa, Bacillus cereus, Serratia marcescens, Proteus vulgaris, Alcaligenes fecalis, Alcaligenes metalcaligenes, Achromobacter liquefaciens, Achromobacter recti,* and *Achromobacter bookeri.* These cultures were inoculated into a synthetic sewage (4) and the 5-day B.O.D. of each was determined. With some of the cultures, B.O.D.'s were obtained, while others gave no B.O.D. With those organisms able to oxidize the sewage, however, the B.O.D.'s obtained varied widely with the numbers of organisms used in the inocula. A typical result is given in Figure 1.

The experiments described herein were conducted to compare the reproducibility of the special 2-day B.O.D. test of Zehnpfennig and Nichols with the standard 2-day and 5-day B.O.D. tests and to see what changes took place in the microbial flora of the sewage as a result of filtration and incubation.

Reproducibility

Since the special 2-day B.O.D. test had shown greater reproducibility than the standard 5-day B.O.D. test with settled sewage, this test was designed

to compare its reproducibility with both the standard 2-day and 5-day B.O.D. tests using raw sewage within given days. On 10 different days, samples of raw sewage were collected at the sewage treatment plant of the A. and M. College of Texas. These samples were allowed to settle overnight at 5° C. before the supernatants were siphoned off. With aliquots of these supernatants, triplicate standard 2-day and 5-day B.O.D. tests were set up. Two 100-ml. aliquots of each sample were placed in 250-ml. flasks and autoclaved. When these had cooled, an aliquot of the raw sewage was filtered through a fine-pore, sintered-glass filter and 1 ml. of the filtrate was used to inoculate one of the sterile 100-ml. portions. This was then incubated for 24 hr. at 20° C. Following incubation, triplicate special 2-day B.O.D. tests were set up, using the sterile sewages as the substrates and 1 ml. of the filtered and incubated sewages as the inocula. Sterile B.O.D. bottles and sterile dilution water were also used. The results are shown in Table I.

The means of the per cent deviations obtained show a satisfactory reproducibility for all three procedures (2.2 to 5.7 per cent). The special 2-day test, however, shows the highest reproducibility while the standard 5-day test shows the lowest. Examination of individual tests, moreover, shows that on no single day was the deviation

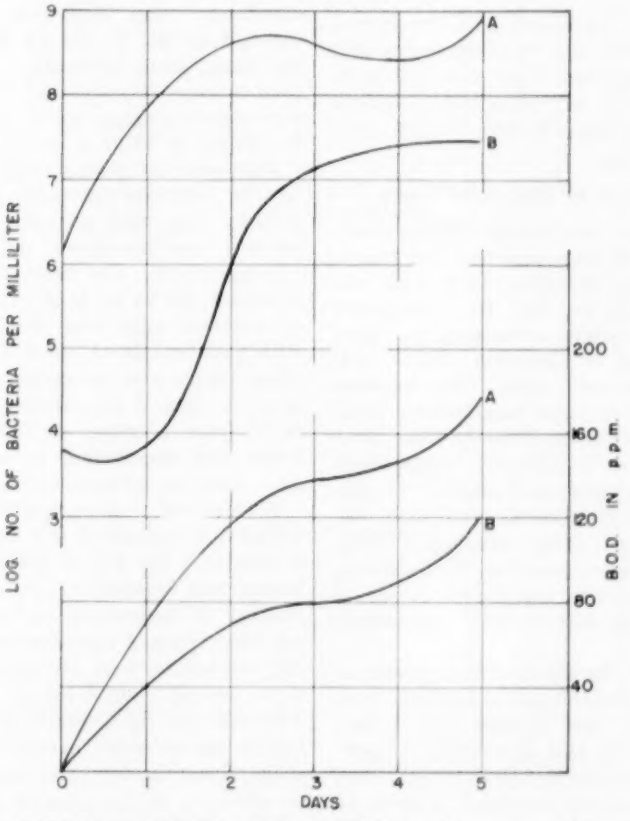


FIGURE 1.—Variation of B.O.D. with *Pseudomonas aeruginosa*.

TABLE I.—Comparison of Reproducibility of Special 2-Day with Regular 2-Day and 5-Day B.O.D. Tests

Sample No.	Special 2-Day		Standard 2-Day		Standard 5-Day	
	B.O.D.[1]	% Dev.	B.O.D.[1]	% Dev.	B.O.D.[1]	% Dev.
1	151	2.0	195	5.1	255	3.9
2	363	1.1	544	6.4	760	7.0
3	510	1.4	293	1.7	445	1.6
4	192	4.2	197	2.0	325	5.8
5	122	0.8	164	3.0	258	3.1
6	117	0.0	193	1.6	345	1.5
7	103	2.9	225	2.2	253	6.7
8	100	5.0	127	1.6	204	3.9
9	192	1.0	238	8.8	263	18.8
10	104	3.9	99	10.1	172	4.7
Mean	195	2.2	228	4.3	328	5.7

[1] Average of three determinations.

more than 5 per cent with the special test, whereas the standard 2-day test and the standard 5-day test each have 4 days and 1 day when the deviations were more than 5 and 10 per cent, respectively.

Changes in Microbial Flora

In their conclusions, Zehnpfennig and Nichols suggested that the reason for greater reproducibility with the special 2-day test was the development of an inoculum containing a "preponderance of bacteria which will oxidize sewage" since "the bacteria present in greatest numbers in fresh sewage are not necessarily those most active in its oxidation." Since they gave no experimental evidence to support these conclusions and since the authors had some experience with changing microbial flora, the following experiment was conducted to see if Zehnpfennig and Nichols' conclusions were valid.

In brief, the experiment consisted of isolating pure cultures of bacteria from aliquots of raw sewage, before and after filtering and incubating the sewage, and making B.O.D. determinations using additional sterilized aliquots of the same sewage as the substrate with the isolated bacteria as the inocula. The entire experiment was run four times. The complete procedure was as follows:

Approximately 8 l. of raw sewage were collected between 9 and 11 A.M. and allowed to settle overnight at 5° C. The supernatant was drawn off, mixed, and divided into aliquots. Approximately 40 portions of 100 ml. each were placed in Erlemeyer flasks and sterilized by autoclaving. A 1-ml. portion was used to make dilutions and pour plates using nutrient agar as the plating medium. These plates were incubated for 48 hr. at 20° C. An additional portion was put through a fine-pore, sintered-glass filter and 1 ml. of the filtrate was inoculated into one of the 100-ml. portions which had been sterilized. This flask was then incubated at 20° C. for 24 hr. From this flask, after incubation, 1 ml. was used to make dilutions and pour plates with nutrient agar. These plates were incubated for 48 hr. at 20° C.

Following the growth of the bacteria on the two sets of pour plates, 55 colonies from each set were randomly marked and transferred to tubes of nutrient broth. The broth tubes were incubated for 24 hr. at 20° C. A plate of nutrient agar was then streaked with each isolate to check its purity. These plates were incubated for 48 hr. at 20° C. and, if the cultures appeared to be pure, a colony of each was selected and transferred to a nutrient agar slant for subsequent use.

With a total of more than 400 isolates in the four repeats of this experiment, determining the B.O.D. given by each isolate was impossible. To lessen the number of determinations and to find out what types of organisms were present, the isolates were divided into what were termed "physiological groups." This was done by determining for each isolate its colonial morphology, cell shape, Gram reaction, and motility, and its ability to reduce nitrates, to liquefy gelatin, and to ferment glucose, lactose,

and sucrose. All of these tests were carried out using standard bacteriological techniques with incubation at 20° C. for 48 to 72 hr., depending on the test. A "physiological group" was then defined as a group of isolates having similar morphology and physiological reactions to these tests. In some instances, these "groups" are synonymous with species; in others, to genera;

TABLE II.—Shift in Bacterial Population of Raw Sewage Following Filtration and Incubation

Physiological Grouping (All Gram-Negative Rods)						Total Number of Organisms Isolated		Average 2-Day B.O.D. (p.p.m.)
Fermentation			NO_2 Red.	Gel. Liq.	Motility	Raw	Filtered and Incubated	
Glucose	Lactose	Sucrose						
(a) Gaseous Fermenters								
⊕	⊕	⊕	+	+	+	2	1	25
⊕	⊕	⊕	+	−	+	31	14	0
⊕	⊕	⊕	+	−	−	44	0	0
⊕	⊕	+	+	−	+	13	3	0
⊕	⊕	+	+	−	−	2	1	0
⊕	+	⊕	+	−	−	4	0	0
⊕	⊕	−	+	−	+	7	0	<10
⊕	⊕	−	+	−	−	3	0	0
⊕	−	⊕	+	+	+	8	0	0
⊕	−	⊕	+	−	+	5	1	<10
					Total	119	20	
(b) Acid Fermenters								
+	+	+	+	+	+	3	0	68
+	+	+	+	−	+	4	0	<10
+	+	+	−	−	+	2	0	10
+	+	+	−	−	−	2	0	85
+	−	+	+	+	+	3	0	0
+	−	+	+	−	−	3	1	0
+	−	−	−	+	+	1	1	0
+	−	−	−	−	+	3	0	<10
+	−	−	−	+	−	0	3	65
					Total	21	5	
(c) Non-Fermenters								
−	−	−	+	−	+	7	4	116
−[1]	−	−	−	+	−	2	0	70
−	−	−	−	+	−	0	2	35
−	−	−	−	−	+	3	15	57
−	−	−	−	−	−	36	155	0
−[2]	−	−	−	−	−	0	2	60
					Total	48	178	
					Grand Total	188	203	

[1] Yellow pigmentation.
[2] Pleomorphic.

TABLE III.—Summary of Findings of Study of Changes in Microbial Flora

Kinds of Bacteria	Total No. Isolates		Total No. Phys. Groups	
	Raw	Filt.	Raw	Filt.
G+, sporeforming rod	2	0	2	0
G − rod, gaseous fermenter	124	22	17	7
G − rod, non-gaseous fermenter	33	9	15	6
G − rod, non-fermenter	51	177	5	5
G − rod, pleomorphic, non-fermenter	0	2	0	1
Total	210	210	39	19
Total showing sig. B.O.D.	19	18	7	8
% showing sig. B.O.D.	9.0	8.6	17.9	42.1

and in others, to broad groups such as coliforms. To have identified all isolates would have been exceedingly time and material consuming, with little additional information gained.

From each of the physiological groups, one culture was randomly selected to determine its ability to oxidize sewage. The culture was inoculated into one of the 100-ml. aliquots of sterilized sewage and incubated for 24 hr. at 20° C. A second portion of the sterilized sewage was then used as the substrate and 1 ml. of the sewage culture as the inoculum in determining the culture's ability to give a B.O.D. The B.O.D. bottles and dilution water used were sterilized and determinations were run after 2 days at 20° C.

Results and Discussion

Partial results are given in Table II. Those physiological groups isolated only one time during the four runs were omitted. They represent only a small percentage of the total isolates and could have little significance in the obtaining of improved reproducibility. Table III gives a summary of all isolates and physiological groups.

From the results, it is obvious that "the preparation of an inoculum of filtered sewage in autoclaved sewage" does not insure "the preponderance of bacteria which will oxidize sewage." The number of bacteria capable of oxidizing sewage was approximately the same before and after the processing.

However, the processing of the sewage did have a marked effect on the numbers and kinds of bacteria present. The average bacterial counts on the raw and processed sewages were 3.5×10^6 and 49.5×10^6 bacteria per milliliter, respectively. The number of different kinds of bacteria in the processed sewage was only about one-half the number found in the raw sewage. There was a decrease of more than 80 per cent in the numbers of gaseous fermenters and an increase of about 270 per cent in the numbers of non-fermenters following filtration and incubation. This increase is probably the most anomalous finding of this study, because it is almost entirely a reflection of the increase of one physiological group. This group gave a negative result to all of the physiological tests and gave no B.O.D., yet was able to multiply tremendously in the sterile sewage, as is shown by the fact that only 16 per cent of the isolates from the raw sewage belonged to this group, while 74 per cent of those from the processed sewage fell within it.

While anomalous, the foregoing result was not entirely unexpected, because the special 2-day B.O.D. test almost consistently gave a lower reading than the standard 2-day B.O.D. test (Table I) even though the processed sewage had a far greater number of

bacteria per milliliter. This serves to illustrate that the B.O.D. obtained from a given sewage varies not only with the amount of organic matter present, but also with the number of organisms capable of oxidizing that sewage, and not with the total number of organisms present.

In spite of the scope of these experiments, no explicit explanation can be given for the improved reproducibility of the 2-day B.O.D. test of Zehnpfennig and Nichols. It may be due to the action of the non-fermenting, non-oxidizing group last discussed when in a more complex environment. Other laboratory tests, not reported herein, to demonstrate synergism with this organism, were unsuccessful. These studies do not preclude the possibility that synergism occurs, however, in the B.O.D. bottle. The improved reproducibility may be due to the marked decrease in the varieties of bacteria present in the filtered and incubated inoculum. It also may be entirely a result of the removal of the bacterial-ingesting protozoa. It seems most likely, however, that all three changes are involved.

Summary and Conclusions

1. B.O.D. inoculation studies, using pure cultures and sterile synthetic sewage, were conducted under sterile conditions. Some organisms gave B.O.D.'s while others gave no B.O.D. With the sewage oxidizers, the B.O.D. varied with the numbers used in the inocula (Figure 1).

2. The special 2-day B.O.D. procedure of Zehnpfennig and Nichols was compared, as to reproducibility, with the standard 2-day and 5-day B.O.D. tests. The special 2-day procedure showed a mean deviation of 2.2 per cent as compared to 4.3 and 5.7 per cent for the other two tests, respectively.

3. The changes in the microbial flora occurring during the preparation of the inoculum for the special 2-day B.O.D. test were studied. No explicit explanation could be given for the improved reproducibility of the special 2-day B.O.D. test. The study did illustrate, however, that the B.O.D. of a given sewage varies not only with the amount of organic matter, but also with the number of organisms capable of oxidizing that sewage, and not with the total number of organisms present.

Acknowledgments

The technical assistance of Mrs. Betty L. Smith and the helpful suggestions of P. J. A. Zeller throughout these studies are gratefully acknowledged.

References

1. Butterfield, C. T., Purdy, W. C., and Theriault, E. J., "The Influence of Plankton on the Biochemical Oxidation of Organic Matter." *Pub. Health Rep.*, **46**, 393 (1931).
2. Sawyer, C. N., Callejas, P., Moore, M., and Tom, A. Q. Y., "Primary Standards for B.O.D. Work." THIS JOURNAL., **22**, 1, 26 (Jan., 1950).
3. Zehnpfennig, R., and Nichols, M. S., "Inoculation Studies in B.O.D. Determination on Sewage and Pulp Mill Waste." THIS JOURNAL., **25**, 1, 61 (Jan., 1953).
4. Butterfield, C. T., Ruchhoft, C. C., and McNamee, P. D., "Biochemical Oxidation by Sludges Developed by Pure Cultures of Bacteria Isolated from Activated Sludge." *Pub. Health Rep.*, **52**, 387 (1937).

HOUSEFLY BREEDING IN SEWAGE SLUDGE

By Harold W. Wolf

Senior Assistant Sanitary Engineer, Communicable Disease Center, U. S. Public Health Service, Savannah, Ga.

Almost everyone is as aware of the disease vectoring capabilities of the common housefly, *Musca domestica*, as of the disease potential of sewage sludge. The desirability of preventing the two from coming into intimate contact is obvious. Yet, despite the best efforts of sewage treatment plant operators, this situation does sometimes occur. Occasionally, in the case of heavy housefly infestations of sludge drying beds, a report will appear in the literature (1).

Many infestations are not reported. The author witnessed two examples in the summer of 1951 at two sewage treatment plants located in the southeastern United States. In one case, the infestation was staggering; a layer of maggots 5 to 6 in. deep was exposed everywhere that the sludge bed was opened for examination. The sludge in both instances was raw.

Fly infestation of sludge drying beds seems to accompany operating difficulties of some kind. Perhaps the plant's digester is overloaded, or accidents or construction activities require the placing of raw or partially digested sludge on drying beds.

The impression one receives from the information available is that the housefly will readily breed in raw or partially digested sludge, but will not breed in well-digested sludge (1)(2).

A study was conducted in the latter half of 1953 to learn more about the relation between housefly breeding and sewage sludge digestion. The work was conducted by members of the USPHS Communicable Disease Center, in the city of Thomasville, Ga., with the full cooperation of the city's sewage treatment plant staff.

Two large industries, a packing plant and a cannery, contributed a substantial load to Thomasville's treatment plant. These industrial wastes were particularly noticeable in the sludge. The population served by sewers was about 14,000 persons, but the population equivalent of the sewage reaching the plant represented that of about 60,000 persons. Average daily dry weather flow at the plant was 2.6 m.g.d. with a 5-day B.O.D. of 460 p.p.m. A brief flow description of the plant is: bar rack, grit chamber, bar screen, primary settling, roughing filter, secondary settling, standard-rate filter, final settling, and an outlet to the Ochlochnee River. Sludge is pumped to a heated (95° F.) digester.

Method

The three 4-l. aspirator-type bottle digesters discussed in this report were mounted in a 95° F. cabinet and operated at detention periods (by displacement) of 5, 15, and 40 days. (Other intermediate detention periods were also studied, but operational difficulties prevented the withdrawal of uniform sludges.) Sludge capacity in all bottles was maintained at 3 l. The bottles were tilted forward at an angle of about 30° to facilitate handling (see Figure 1).

Determinations made on the sludge samples included pH, total solids, volatile solids, and a bio-assay. Assays of pH and solids were conducted according to "Standard Methods" procedures (3). A bio-assay test was developed for this study and was performed as follows: approximately 100 g. of sand was placed in a 1-pt. Mason jar, then 50 ml. of sludge sample were carefully

added; 20 housefly eggs were imposed on the surface of the sludge; and the jar was covered with a cloth and placed in the insectary. After the larvae had pupated, the puparia were counted and classified by observed size—small, medium, or large. The large size was considered to be on a par with the size of puparia normally reared from artificial rearing media (NAIDM, malt, yeast mixture). It was expected that if the larval environment was well suited to the maggot, a maximum number of normal pupae would develop. Similarly, if the environment was poor, fewer and smaller pupae would develop. Preliminary laboratory studies on 50-ml. quantities of raw sludge indicated that if 10 or 20 eggs were seeded, the pupae that developed would be large. If 30, 40, or 50 eggs were seeded, the resultant larvae would be undersized and would take an increasingly longer time to reach the pupal stage. There was no significant difference in the total numbers reaching the pupal stage.

An attractivity observation was performed as follows: Samples of raw, 5-day, 15-day, and 40-day digested sludge were placed upon sand (same quantities as used in the bio-assay) in shallow, open jars and placed in a cage of flies. Observations were made on the numbers of flies on each sample over a two-day period, during which the cage and sample positions were shifted to eliminate any effects therefrom.

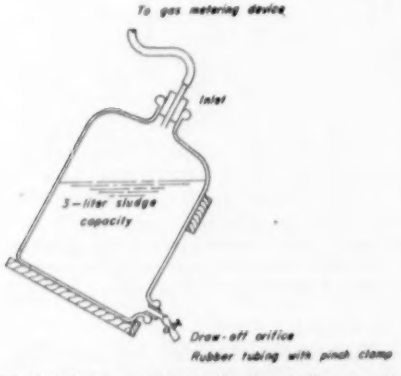


FIGURE 1.—Method of using 4-liter bottle for digestion of sewage solids.

Operation

Raw primary sludge was added to all digesters twice daily (collected at the 7:00 AM and 1:00 PM pumpings). The first addition of sludge to all digesters consisted of well-digested sludge for seeding purposes. The amount of seed sludge was 300 ml. for the 5-day bottle, 100 ml. for the 15-day bottle, and 37.5 ml. for the 40-day bottle.

On the fifth day of digester operation, the 5-day bottle had built up to its 3-l. capacity (600 ml. daily). Hence, on the morning of the sixth day (and daily thereafter) 600 ml. were withdrawn, then 300 ml. of raw sludge were added, and in the afternoon another 300 ml. of raw sludge were added. This same operational procedure applied to all three bottles, except for varying quantities.

Sludge was collected by the plant operator in a 1-gal. glass container. The contents were mixed thoroughly and passed through ¼-in. hardware cloth to remove large particles which might otherwise clog the outlet orifices of the small digestion tanks. After sieving, the sludge was again thoroughly mixed and then was portioned out to the digesters and sample jars. Samples of sludge withdrawn from the digesters were also placed in jars and all samples were taken to the insectary for the determinations. The digesters were operated continuously 7 days a week, but determinations were run only on the samples collected between Monday and Friday.

Results and Discussion

Although sampling commenced with the beginning of the study, the early data are not presented in Tables I and II because of erratic digester performance during the first months of operation, resulting in atypical sludge. For example, the first sludge withdrawn from the 5-day bottle digester was simi-

TABLE I.—Digester Loadings and Summary of pH and Solids for Raw Sewage Sludge and Sludge Digested for 5-, 15-, and 40-Day Periods[1] in 4-Liter Bottle Digesters at 95° F.

Sludge	pH[2]		Total Solids[3]		Vol. Solids[3]		Digester Loadings		Gas Production
	Mean	Number Samples	(%)[4]	Number Samples	(%)[4]	Number Samples	Vol. Sol. (lb./cu. ft./day)	Tot. Sol. (lb./cu. ft./day)	(cu. ft./lb. vol. sol. added)
Raw	5.6	37	5.5	77	72	61	—	—	—
Digested 5 days[1]	5.2	20	8.9	41	68	34	0.494	0.686	0.86
Digested 15 days[1]	7.2	19	6.8	34	64	30	0.167	0.229	5.89
Digested 40 days[1]	7.8	12	4.9	24	52	20	0.062	0.085	9.92

[1] Time of digestion based on displacement.
[2] From period between 115th and 142nd days of operation.
[3] Samples taken between 91st and 156th days of operation, except for period between 133rd and 141st days, when no volatile solids determinations were made.
[4] Average.

lar in physical characteristics to well-digested sludge because of the initial seed. On succeeding days the sludge became grayer, stickier, and more odorous until about the 25th day, after which it remained constant. The sludge drawn from the 5-day digester during the first 25 days was, therefore, excluded from test results.

The change in the 15-day bottle digester occurred about the 70th day, although it was not nearly as marked as in the 5-day digester. Sludge from the 5-day digester was typically that of the acid phase of decomposition, while in the 15-day digester enough alkaline activity was occurring to maintain the pH at 7.2. No change occurred in the 40-day digester.

The results of the bio-assay testing (Table II) include only those samples which were statistically comparable. To minimize the effects of any biological variation in the housefly population, each run was seeded with eggs from the same batch, at the same time, and held under similar insectary conditions.

TABLE II.—Summary of Bio-Assay and Attractivity Studies Performed on Raw Sewage Sludge and Sludge Digested for 5-, 15-, and 40-Day Periods, in 4-Liter Bottle Digesters at 95° F., Utilizing *M. domestica*

Sludge	Bio-Assay[1]						Attractivity[4]	
	Total No.[2] Fly Eggs Imposed	Total No. Pupae Developed	Per Cent Pupae Developed	Pupae Size (%)[3]				
				Large	Medium	Small	First Day	Second Day
Raw	400	202	50.5	95	5	0	1.42	16.79
Digested 5 days	400	258	64.5	63	34	3	7.60	11.58
Digested 15 days	400	238	59.5	54	12	34	1.45	8.53
Digested 40 days	400	240	60.0	14	19	67	1.60	2.84

[1] Includes only those samples which were seeded together after the 90th day. The means on the raw and on the 40-day sludge were not different from their respective means of all raw and all 40-day samples taken during this period. (Raw $n = 99$; $\bar{X} = 10.80$; $t = 0.52$: 40-day $n = 47$; $\bar{X} = 13.61$; $t = 1.04$).
[2] 20 samples of 20 eggs each.
[3] Based on the following numbers of pupae: Raw 728, 5-day 307, 15-day 287, and 40-day 279.
[4] Values represent the mean number of flies noted on the different types of sludge at any particular moment.

The apparently greater number of flies reaching the pupal stage in the 40-day sludge as compared to the raw sludge is not statistically significant. Whereas there is little variation in the numbers of pupae, there is large variation in their size. Of the pupae from raw sludge, 95 per cent were large, none small; 14 per cent of the pupae from the 40-day sludge were large and 67 per cent were small.

The results of the attractivity observation (also presented in Table II) represent the means of each day's observations on each sludge sample (20 observations the first day, 19 the second). The highly odorous 5-day sludge had the highest mean the first day, whereas the raw sludge had the highest mean the second day. If the fly factor (4) were involved, the second day's results for the 5-day sludge would have been considerably higher than the others.*

During the first day, the observed mean number of flies noted on the 5-day digested sludge was considerably higher than that for the other three samples. In view of the second day's results, this is rather unusual. It is believed that this is due primarily to the low moisture content of the 5-day sludge (see Table I). According to Von Zuben *et al.* (1), "Partially digested sludge in drying beds or lagoons will attract houseflies, and egg deposition will occur as soon as the sludge dries to the extent that flies can rest upon it, usually within 12 hr." The 5-day sludge in this study was uniformly thick (it had to be scraped out of the bottle) and did not have to dry, as did the other three samples, before flies could rest upon it. A secondary factor which may have contributed to these results was the intense odor of the 5-day sludge.

* The fly factor is a phenomenon associated with attractivity. The housefly apparently produces or bears a substance attractive to other houseflies. Hence, a bait which had had many flies recently upon it would be more attractive than similar bait not so visited, other things being equal (4).

The results of the second day's observations on attractivity indicate that the housefly's attraction to sludge decreases as the detention period (or degree of digestion) of the sludge increases.

According to Tables I and II, there is no relation between the results of the bio-assay and the pH and total solids. There is a relation between pupal size and volatile solids; the higher the volatile solids content, the greater the percentage of pupae that are large.

Laboratory studies with artificial housefly rearing media performed in the insectary at Thomasville demonstrated a rather wide "optimum" moisture content based on numbers of flies, ranging at least between 60 and 75 per cent. As "sludge cake," the name commonly applied to sludge when it can be forked from drying beds, has a moisture content of 60 to 70 per cent (5), it is doubtful if moisture is a limiting factor in housefly production from drying beds.

Summary and Conclusions

Sewage sludge from the city of Thomasville, Ga., was digested in small bottle digesters for periods of 5, 15, and 40 days (displacement basis). Bio-assays with housefly larvae on these sludges and on raw sludge revealed the following:

1. Houseflies will breed in 40-day digested sewage sludge under laboratory conditions. That they will breed in well-digested sludge on drying beds under field conditions was witnessed during a time of extreme housefly population pressure.

2. The pH, total solids, volatile solids, and moisture content (within the usual range of sewage treatment plant operation) have no significant effect on the numbers of housefly pupae produced. A relation appears to exist between the percentage of volatile solids and pupal size; the higher the volatile solids content of the sludge, the greater the percentage of pupae that are large.

3. The amount of nutrient available in sludge to housefly larvae is apparently reduced by the digestion process as indicated by pupal size.

Acknowledgments

The author wishes to express his appreciation to Ronard Van Dame and Marion Hicks, superintendent and chief operator, respectively, of the Thomasville sewage treatment plant for their wholehearted cooperation; to Eugene C. Palmer and Alvin Paulk, Communicable Disease Center, USPHS, for biological assistance; and to Emmarie Hemphill, also with the Communicable Disease Center, for her statistical assistance.

References

1. Von Zuben, F. J., Ogden, L. J., and Peel, R. E., "House Fly Breeding at Sewage Treatment Plants in Texas." THIS JOURNAL, **24**, 10, 1303 (Oct., 1952).
2. Goudey, R. F., "New Thoughts on Sludge Digestion and Sludge Disposal." *Sewage Works Jour.*, **4**, 4, 609 (July, 1932).
3. "Standard Methods for the Examination of Water and Sewage." 9th Ed., p. 159. Amer. Pub. Health Assn., New York, N. Y. (1946).
4. Barnhart, C. S., and Chadwick, L. E., "A 'Fly Factor' in Attractant Studies." *Science*, **117**, 104 (Jan. 30, 1953).
5. Babbitt, H. E., "Sewerage and Sewage Treatment." 6th Ed., p. 524. John Wiley & Sons, Inc., New York, N. Y. (1947).

CONFERENCE ON BIOLOGICAL WASTE TREATMENT

A three-day Conference on Biological Waste Treatment has been announced for April 13–15, 1955, by Manhattan College, New York City. The conference is for the presentation of authoritative papers containing information on the principles of biological treatment processes and their application to the design of waste treatment facilities.

Additional information concerning the conference may be obtained from Professor W. W. Eckenfelder, Civil Engineering Department, Manhattan College, New York 71, N. Y.

SCIENTIFIC BASIS FOR LIMING OF DIGESTERS

A DISCUSSION

By Peter J. Neuspiel and Philip F. Morgan

Research Associate and Professor of Sanitary Engineering, respectively, State University of Iowa, Iowa City, Iowa

Sawyer, Howard and Pershe (1) have demonstrated that the addition of lime in amounts equivalent to as high as 200 per cent of the volatile acids is beneficial to a "pickled digester."

Another study, one to ascertain the effectiveness of liming in starting digestion without seed sludge, was carried on in the laboratory at the Iowa City sewage treatment plant in the summer of 1953.

Each of four 8-l. aspirator bottles was provided with a raw sludge feed line, a sludge withdrawal line, a gas production line, and a gas recirculation line, and all were operated at 35° C. This setup is similar to that used in some of the earlier Iowa City studies (2).

The study was begun by filling each of the four digesters with 5,400 ml. of effluent and 150 ml. of raw sludge from the primary clarifiers. For the first 38 days, the sludge addition to each digester was 150 ml. per day. Immediately after each feeding, 1 l. of the gas previously produced in each digester was diffused through the contents by means of a porous diffuser located near the bottom center of each unit. To digesters No. 1 and No. 2, a sufficient quantity of lime was added daily with the raw sludge to maintain the pH of the digester contents above 6.5 at all times. This was continued for 30 days until the pH remained above 6.5 without lime addition. No lime was added to digesters No. 3 and No. 4.

The volume of the contents in each digester was maintained between 5,400 and 6,000 ml. at all times by withdrawing sludge from each of the digesters twice each week during the first 38 days, and more frequently thereafter as the feeding was increased.

Immediately before the sludge was withdrawn the contents of the digesters were manually mixed so that the sample collected was representative of the entire contents. Solids determinations were made on these samples and on all raw sludge samples. Volatile acids determinations were made on the contents at frequent intervals. The quantity of gas production and the pH of the digester contents were determined daily before raw sludge was added. The results of the pH determination were used as a guide for determining the lime dosage for digesters No. 1 and No. 2.

At the end of 38 days the volatile acids in digesters No. 1 and No. 2 had decreased from 1,800 to 800 p.p.m., the gas production had increased from 0 to about 10 cu. ft. per pound of volatile solids added, and the pH had stabilized at approximately 7.0. This was taken as an indication that normal digestion was commencing, so the loading of these digesters was gradually increased to 600 ml. per day (Figure 1). At the end of 50 days digestion was normal, as indicated by volatile acid concentration, pH, and gas production, at the design loading of about 0.25 lb. of volatile solids per cubic foot per day. It continued normal to the 57th day, at which time these units were taken out of operation.

Although the loading to all four digesters up to the 38th day was identi-

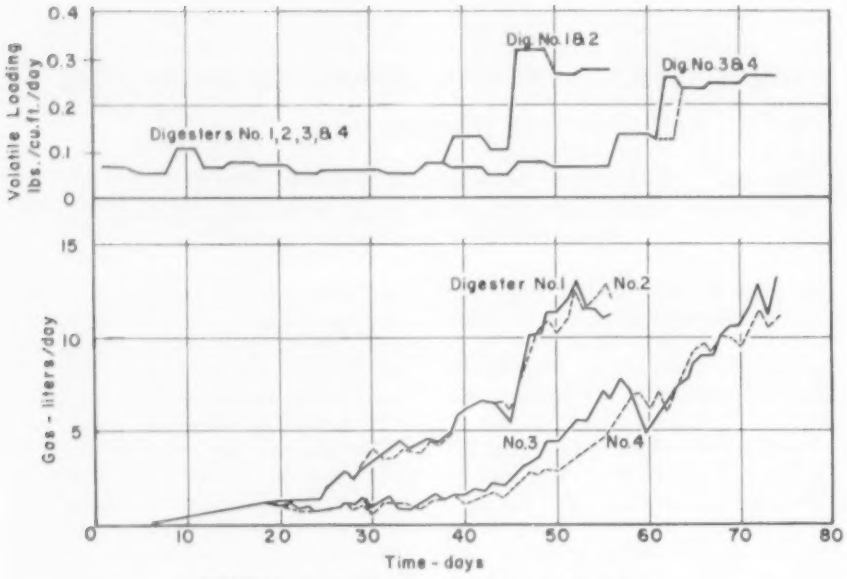


FIGURE 1.—Daily gas production and loading.

cal, the gas production on the 38th day in digesters No. 1 and No. 2 (with lime) exceeded that of the others by three times (Figure 1). The progress towards normal digestion in digesters No. 3 and No. 4 was slower, but at the end of 75 days they too were digesting normally.

The total of 40 g. of lime added to both digester No. 1 and digester No. 2 at a rate of not more than 2 g. per day is equivalent to an average rate of addition of about 14 lb. of lime per 1,000 cu. ft. of digester capacity per day. The cost of this would not be prohibitive, but the decision as to whether lime is to be used should rest upon the urgency of the need for full digestion capacity, and for gas for heating or power generation. Normal digestion in all the experimental digesters was obtained with the accelerated sludge digestion process within a period of 11 weeks, although the addi-

TABLE I.—Average Results of Digester Liming Experiments

10-Day Period	pH				Gas Prod. (cu. ft./lb. vol. added)				Vol. Acids (p.p.m.)			
	Dig. 1	Dig. 2	Dig. 3	Dig. 4	Dig. 1	Dig. 2	Dig. 3	Dig. 4	Dig. 1	Dig. 2	Dig. 3	Dig. 4
1	6.65	6.70	6.00	6.05	0.23	0.24	0.37	0.33	1,140	1,120	1,050	1,150
2	6.60	6.60	5.80	5.60	2.21	2.14	2.26	2.10	1,550	1,590	1,520	1,750
3	6.70	6.70	6.10	6.00	6.06	6.17	2.88	2.26	1,460	1,420	1,650	1,870
4	6.85	6.85	6.20	6.20	10.5	9.79	3.27	3.13	1,040	1,100	1,650	2,000
5	6.95	6.95	6.30	6.30	7.19	7.23	7.25	5.27	410	460	1,840	1,980
6	6.95[1]	6.95[1]	6.80	6.55	7.25[1]	7.36[1]	11.87	9.36	340[1]	320[1]	1,050	1,890
7	—	—	6.85	6.80	—	—	6.19	7.21	—	—	930	870
8	—	—	7.00[2]	6.90[2]	—	—	8.00[2]	7.28[2]	—	—	500[2]	510[2]

[1] 7-day average.
[2] 6-day average.

tion of lime accelerated the onset of digestion in digesters No. 1 and 2 about 3 weeks.

In this study, the effectiveness of the addition of lime was undoubtedly enhanced by the intimate mixing obtained by the gasification of the raw sludge, lime, and the digesting sludge. Such results might not be obtained without it.

Although both studies show that lime can be beneficial in the control of the digestion process, one difference in the results reported in the two should be noted. In the Iowa City studies, the volatile acids were relatively high in the beginning (Table 1), but were considerably lower than those reported by Sawyer *et al.* (1). Probably this can be explained by the fact that the digesters were gradually filled with sludge in the presence of primary effluent, which provided dilution for the end products of digestion, rather than being "bulk loaded."

Acknowledgment

The work reported herein was supported by the Chicago Pump Company and was carried on at the Iowa City sewage treatment plant.

References

1. Sawyer, C. N., Howard, F. S., and Pershe, E. R., "Scientific Basis For Liming Digesters." THIS JOURNAL, **23**, 8, 935 (Aug., 1954).
2. Morgan, P. F., "Studies of Accelerated Digestion of Sewage Sludge." THIS JOURNAL, **26**, 4, 462 (Apr., 1954).

PERUVIAN FACILITIES FOR SANITARY ENGINEERING BEING STRENGTHENED

The University of North Carolina recently entered into a three-year contract with the Institute of Inter-American Affairs of the United States Foreign Operations Administration for the purpose of strengthening the sanitary engineering educational and research programs in the National School of Engineering of Peru. The contract, which calls for the expenditure of some $185,000, will be administered by the University's School of Public Health through its Department of Sanitary Engineering.

Three members of the staff of the Department of Sanitary Engineering will go to Peru for varying periods of time during the first year. Other faculty of the School of Public Health will participate later in the program.

Among the purposes of the project is the integration of laboratory teaching into the five-year sanitary engineering under-graduate program of the National School of Engineering and the initiation and development of sanitary engineering research. This will require the preparation of curricula, equipping of laboratories, and training of teachers and research workers. The National School of Engineering has just completed the construction of modern quarters in Lima to house their Department of Sanitary Engineering.

Faculty and engineers from Peru will also come to the United States under this project for special training so that they may return to Peru and continue with the developments initiated.

Industrial Wastes

LAGOONS FOR TREATING METALWORKING WASTES

By Charles R. Griffith

Waste Engineer, Dana Corporation, Fort Wayne Division, Fort Wayne, Ind.

A number of articles on lagoons have been written, but the novelty of one in particular (1) lay in the fact that industrial wastes—particularly oil emulsions, acid wastes, and alkaline wastes—were amenable to such treatment. The lagoons mentioned in that paper were used from 1946 to the Fall of 1951, when construction of a new Dana Corporation plant required relocating the waste treatment lagoons. During its period of operation the original system performed most satisfactorily; therefore, after consideration of various methods, it was decided that a new lagoon system would be provided to handle the wastes of both the new Aircraft Gear plant and the Salisbury Axle plant.

The Salisbury Axle plant was started in 1946 and manufactures differential axles for automobiles. The Aircraft Gear plant started production of gears for aircraft in 1952. Although both plants are operated as separate divisions of the Dana Corporation, they do share power and waste treatment facilities.

Property and Plant Details

Two separate buildings, totaling about 23 acres under roof, are located on a 95-acre plot on the northwest edge of Fort Wayne, Ind. The buildings are on the southern half of the property, whereas the northern acreage, which is about 30 ft. lower than the southern part, is used for the lagoon system and a parking lot for the Aircraft Gear building. Because of the elevation of this land, it was subject to flooding by the Neuhaus Ditch, a small creek at the north edge of the property (Figure 1). Such flooding was not considered detrimental to the lagoon system, and since fill was available to raise only the parking lot above flood stage, this low land was available for the use that was made of it. The difference between the elevations of the plant and of the lagoons permits good use to be made of gravity flow in handling wastes and in providing some aeration in the treatment.

Sources of Wastes

The two plants are similar in nature, both consisting primarily of a large number of operations requiring cutting and grinding of steel, and other processes related to finishing and assembly. Table I lists the types of wastes to be handled, their sources, and the methods of disposal.

Three separate sewer systems serve the two buildings and the powerhouse so that wastes may be segregated at the source. Segregation is made on the basis of the type of waste, with some consideration given to convenience and costs. Such compromising for convenience and costs is limited to cases where cooling water may be piped to a process sewer rather than to the storm sewer, but under no circumstances is the reverse permitted; that is, a process waste can never be put into a storm sewer. To maintain control over all changes in sewerage, a form is required to be filled out in complete de-

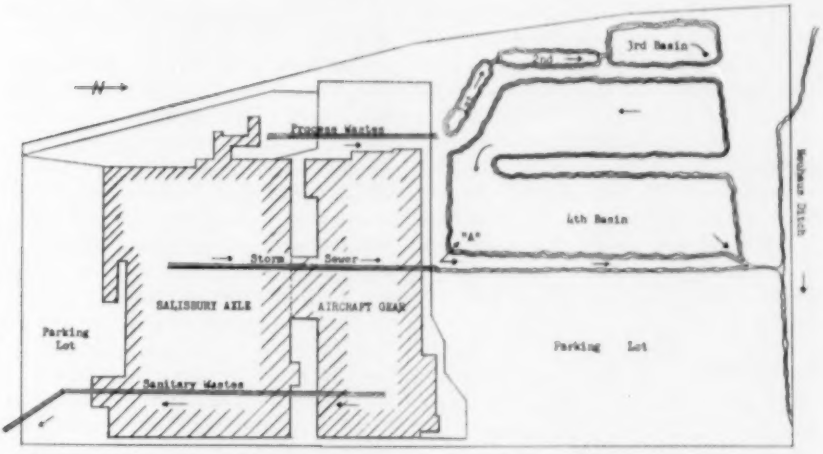


FIGURE 1.—Plant lot layout, showing location of the three main sewers, the lagoons, and the receiving ditch.

tail for changes or new connections. This form must then be approved by the Chief Chemist and the Plant Engineer before any work on the project may begin. Figure 1 indicates the flow of the various wastes through the sewer systems.

Treatment Process

All process wastes from both plants are collected by a system of lateral sewers, which connect to a main line discharging into the first basin. Flow to the first basin averaged about 200 to 250 g.p.m. during the 16 months covered by this paper. At this flow, the theoretical detention time is about three days for the first basin. During the actual detention time, which is known to be much less than the theoretical value first given, readily separating oils and solids rise, or sink, according to their specific gravity. At the effluent end of this basin is a concrete overflow structure. Wastes flowing to the second basin must pass under a baffle that retains separated oil and other floating matter. At this point an

TABLE I.—Sources and Disposition of Process Wastes

Type	Source	Disposal
Soaps and alkaline cleaners	Washing operations	Process sewer
Acid cleaners	Cleaning and surface treatment processes	Process sewer
Oils, mineral	Equipment leaks, grinding, chip drainage	Process sewer
Oils, emulsified	Cutting, grinding, etc.	Process sewer
Solvents, emulsions	Cleaning operations	Process sewer
Paint	Spray booths	Process sewer
Boiler compound	Boiler and water treatment	Process sewer
Other acid wastes	Coal pile drainage	Process sewer
Plating wastes	Cyanide and chrome plating	Process and sanitary
Sanitary wastes	Plant restrooms and cafeteria	Sanitary sewer
Cooling water	Plant processes	Storm sewer
Storm water	Buildings and grounds	Storm sewer

adjustable slotted pipe is used to skim the oil from the surface. Flow through the slotted pipe collects in a pit, where it is pumped to tank trucks for disposal by a private contractor. While the influent to the first basin showed an average oil content of 2,543 p.p.m., and suspended solids of 1,484 p.p.m., the effluent averaged 92.2 p.p.m. oil and 79.0 p.p.m. suspended solids, or a reduction of 96.4 and 94.7 per cent, respectively. B.O.D. reduction amounted to 74.2 per cent.

Second Basin

The second basin is similar in shape and size to the first, and performs the same functions; but the percentage reductions are much smaller. Oil content drops another 1.8 per cent, suspended solids 2.0 per cent, and B.O.D. 9.5 per cent. An identical overflow structure is available for skimming oil, but it has not been used to date and will not be needed unless, or until, the first basin loses its efficiency. It is planned to clean these basins by clamshell as required. Analytical results show that approximately 2 tons of dry solids are deposited in the first basin each working day, while the second basin received less than 100 lb. per day. With such loadings, it is contemplated that the first basin may require cleaning about every 5 years, and the second basin not more than once every 25 years.

Third Basin

The third basin originally was planned as part of the final basin, but due to the need of treating the wastes of one plant while the second was being built and which required relocation of the waste treatment system, it was necessary temporarily to use what is now the third basin as a final basin. When the relocation of the waste system was complete, a siphon overflow was installed instead of removing the common dike between the basins. This decision has made possible better analytical observations and permits additional aeration of the waste.

The third basin has an area of slightly less than 1 acre. Detention is calculated to be about 96 hr. The waste effluent from the second basin receives greater aeration than occurs between the first and second basins and this additional aeration, plus a larger exposed surface area (more than double the preceding basin, but only one-fourth the depth), tends to build up the oxygen content so that some aerobic action may take place. This is the chief difference from the preceding basins, as they are devoid of oxygen. Oil content is lowered another 0.6 per cent, suspended solids 0.7 per cent, and B.O.D. 6.9 per cent.

Fourth Basin

Additional aeration takes place as the flow enters the fourth basin, which has approximately 11 acres of surface area. Theoretical detention time is 40 days. This basin is bisected by a dike to channel the flow from the fourth basin inlet to the outfall to the creek. The outfall structure, located at the northeast edge of the basin, discharges the effluent continuously over a concrete weir to a small creek at the north edge of the property. Considerable aeration or deaeration, depending upon the oxygen content of the effluent, takes place in dropping from the weir to the flow line of the creek. Provisions have been made in this structure to prevent floating algae, oil slick, or debris from discharging to the stream. Two 24-in. shear gates permit drainage or flushing of this basin, if required.

The final effluent shows an average over-all reduction of 99.5 per cent for oil, 99.2 per cent for suspended solids, and 97.9 per cent for B.O.D., compared to the influent to the first basin. The receiving stream is so small that in dry weather the fourth basin effluent accounts for 80 per cent of the stream flow. This stream in turn joins a slightly larger stream in a city park

about 0.5 mi. below the outfall. The larger stream also suffers from low dissolved oxygen content during periods of low flow, sometimes dropping below 0.5 p.p.m. However, this same stream, after receiving the plant effluent, is improved sufficiently to support fish life by the increase in D.O. and additional flow. Normally the storm-water sewer discharges directly to the creek, but during the summer months this flow is diverted to the fourth basin through a structure at point A (Figure 1). This increases the flow over the effluent weir another 100 to 200 g.p.m. to add additional flow to the stream.

The sanitary sewer flows south to a city sewer and then to the Fort Wayne sewage treatment plant.

Discussion

At the time the new plant was designed, consideration was given to several methods of waste treatment and the final decision to continue with the lagoon system was based on the satisfactory performance during the preceding few years. Where many proposed systems offered some particular advantage (such as speed of breaking oil emulsions, minimum space requirements, etc.), none offered a complete treatment (that is, reduction of turbidity, oil, solids, and B.O.D.) and provided the proper alkalinity, pH, and dissolved oxygen content at a minimum cost.

The confidence in the lagoon system, as displayed by the Plant Engineer, other plant officials, and the author, was instrumental in providing the facilities now under discussion. The decision to use this method has been vindicated by the analytical data collected during its period of operation. These data show a most satisfactory effluent. Original construction costs were less than other proposed methods and operating costs are so low that no other proposed method stands comparison. Also, the goodwill created by the successful treatment of industrial wastes has been an asset to the company in its community relations.

The facilities are more than adequate for the present flows, but during the period covered neither of the two plants reached the maximum flows that could be expected in the future. From the effluent data of the various basins, the degree of purification that takes place within a certain time or area is now known. With this information, and with a known requirement of the degree of waste treatment demanded, it is, or would be, a simple matter to reduce the lagoon area if space requirements should become critical. However, since this land was subject to flooding, and since the elevation of this area was lowered further in digging the basins and the removed dirt was used for fill, it is questionable that the reclaimed area now would be of much use for other purposes.

Silva and Papenfuss (2) place emphasis on the importance of design. However, there seems to be some difference in their viewpoint on construction compared to design of the system under discussion. One particular item is the matter of shape and size of the basins. Their preference for large single units may be valid where there is no problem with floating matter. Where oil is involved, efficiency and the safety factor is greatly improved by a series of basins which may retain any oil that normally is released in the secondary treatment. The smaller basins may not be quite as effective in aerating the wastes by wind or wave action. However, where small basins are used as primary settling tanks, the surface would be sealed by floating oil, and when the surface is so sealed the action would be anaerobic. This generally is true of the first basin if it receives a septic sewage. It would seemingly follow that odors would develop but such has not been the case in this system. Lack of odor may be due to the absence of large quantities of or-

ganic matter in the waste. B.O.D. loading amounts to about 12 lb. per acre-foot per day. It has been proposed that the lagoons could successfully handle the additional organic loads from the restrooms and cafeteria, but there has been little need for such treatment as it is capably handled through discharge to the city sewers and thence to the municipal sewage treatment plant.

Another advantage of multiple basins in this particular system is the aeration obtained between basins as purification takes place. This is accomplished by successively dropping the effluent from one basin to the next, and is one reason why the final basin has shown a minimum D.O. of 6.4 p.p.m. on the new system, whereas the original lagoons showed a minimum D.O. of 1.0 p.p.m. These low D.O. values result from operation during the winter months when biological activity has slowed considerably.

By the use of four basins, it is now known just what degree of purification takes place within a certain length of time.

During the cold months, the B.O.D. of the final effluent tends to rise slightly but not to the point where it becomes unsatisfactory. All too often lagooning has been eliminated from consideration except in areas that are sunny and dry. Indiana has considerable variation in weather and temperature so, the satisfactory results of this installation should be a stimulus for consideration of lagoon treatment in other areas that are not sunny and dry. For even more positive proof, the successful use of such treatment in North Dakota (3) should remove any skepticism that might exist.

In a previous paper (1) the theory of purification was covered in some detail. Basically stated, sedimentation, aided by a chemical floc formation inherent in the waste, and biological activity, primarily by the algae, combine to break oil emulsions and to reduce the B.O.D. Jar tests have shown that mere holding of the wastes for a sufficient length of time greatly reduces the turbidity, and the oil and suspended solids contents. What is a sufficient length of time? For the particular wastes involved, a period of 5 to 8 days reduces oil, suspended solids, and B.O.D., and increases D.O. and turbidity. Additional time of detention improves B.O.D. reduction, but has little other beneficial effect.

The possibility of too long detention requires consideration. Since algae are of considerable importance in purification of the waste, it is advisable to provide optimum conditions, not only for sufficient number and types, but for the maintenance of healthy growth. Thus, in any system, with the depletion of the sustaining nutrient healthy algae growth and development must cease. In such cases, the dying algae then increase the organic load and B.O.D. Where loadings may vary, it then becomes necessary to provide some flexibility by limiting or increasing the loading, or providing recirculation or various influent points to better distribute the incoming flow.

In the system under discussion, advantage is taken of the 100- to 200-g.p.m. flow of cooling water as a diluent and purging medium to lessen the detention time. Through control valves, it is possible to take all or part of this flow into the middle of the fourth basin. When this is done, the flow through the final half of this basin, where the nutrient may be low or insufficient, is accelerated and discharges more rapidly to the effluent weir and thence to the stream. With less detention, the algae remain healthy. Undoubtedly during periods when the flow of only one of the plants may require treatment, this diversion of additional flow may well be the only means of providing more nearly optimum conditions.

Plating wastes in the Salisbury Axle plant are of little volume or impor-

tance, but the Aircraft Gear plant has a large plating room to process silver, copper, chrome, and tin plating, and a copper stripping process. To handle these wastes, equipment for treating with chlorine and sulfur dioxide, complete with provisions for chemical precipitation and pH control, was installed. The treated plating wastes are then discharged to the sanitary sewer, although provisions have been made to permit disposal of such wastes to the lagoon system if and when it appears feasible to do so. However, the wastes are segregated in the plating room so that all non-toxic wastes (such as cleaning solutions, acid, and rinse tanks ahead of the plating tanks) are piped to the process lines and thus are clarified in the lagoons. This reduces the volume to be treated and also the charges for the volume handled by the city.

All plating tanks are set over pits capable of holding the combined volume of all such tanks to guard against toxic concentrations reaching the sewer in case of leakage or overflowing. Any drippage or leakage into these pits is then transferred to the plating treatment facilities before discharge to the sanitary sewer.

Results of Tests

Monthly samples are taken and analyzed by the chemical laboratory. The B.O.D. results are from samples analyzed by the Fort Wayne sewage treatment plant. The data (Table II) were based on 10 monthly influent samples and 16 monthly effluent samples. It should be noted that the influent samples are subject to error due to grab sampling, but the effluent samples are fairly representative due to compositing or dilution by the volume of water in each basin. Slugs of waste have been picked up in the influent, but lose their identity before reaching the third basin.

The curves for the B.O.D., turbidity,

TABLE II.—Results of Lagoon Treatment of Metalworking Wastes

Sampling Point	Temp. (° F.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Turb. (%)[1]	pH	Alk. (p.p.m.)		Solids (p.p.m.)		Oil (p.p.m.)
						Phenolphthalein	Methyl Orange	Suspended	Volatile	
Influent:										
Maximum	84	0.0	472	12	8.2	0	306	5,221	5,074	13,438
Minimum	73	0.0	5	57	6.8	0	204	208	116	218
Average	78	0.0	202	29	7.5	0	263	1,484	1,367	2,543
First basin effl.:										
Maximum	88	0.0	102	16	8.0	0	344	127	97	195
Minimum	68	0.0	9	70	6.9	0	220	38	16	21
Average	78	0.0	52	58	7.3	0	267	79	61	92.2
Second basin effl.:										
Maximum	80	0.0	72	36	7.9	0	300	137	115	94
Minimum	56	0.0	5	82	7.0	0	224	20	8	16
Average	68	0.0	33	62	7.5	0	273	51	37	45.1
Third basin effl.:										
Maximum	82	5.0	34	43	8.0	0	296	81	68	61
Minimum	40	0.2	5	95	6.1	0	228	4	3	12
Average	62	1.2	19.1	72	7.5	0	276	38	29	30.4
Fourth basin effl.:										
Maximum	80	14.0	7.3	83	8.8	32	280	25	15	22
Minimum	32	6.0	0.6	99	7.9	0	224	1	0	5.9
Average	54	10.5	4.2	92	8.4	23	249	12	5	11.5

[1] By percentage of light transmission, measured by photelometer; distilled water = 100 per cent.

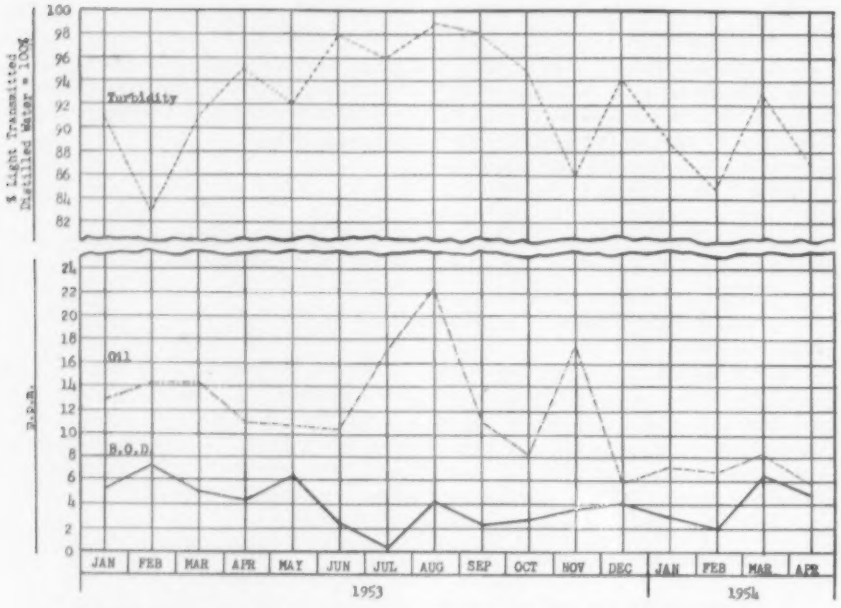


FIGURE 2.—Trends in turbidity, oil content, and B.O.D. of final effluent.

and oil content of the final effluent (Figure 2) are somewhat erratic and follow no definite pattern, but are of interest as control charts and to show trends. The cause of some of the variation is known and a word of explanation is in order.

It has been decided that the system should hold a 15-p.p.m. maximum oil content. This value is based on results recorded when but one plant was discharging to the old system. The new system has done a most satisfactory job in meeting this standard with the exception of three samples (July, August, and November 1953). It is known that the July and August samples were erroneous due to an analytical error in weighing the flask before all the solvent had evaporated. Such an error is not a reflection on the system. However, the November sample was higher due to a sloughing of algae; since it could recur in the future, it should be considered as a variable of the process.

Suspended solids are equally as erratic as the oil content, and the high readings generally are due to inorganic solids following heavy rains, or to sloughing of algae at certain times of the year. The higher suspended solids cause no trouble since they occur during periods of stream runoff or higher flow.

B.O.D. reduction shows a slightly better efficiency during the sunny months, but the effluent has never been unsatisfactory in this respect, regardless of the time of year.

Turbidity and B.O.D. seem to have a direct relationship to each other, as the B.O.D. is lowest when the turbidity is lowest. This can be seen by comparing the turbidity curve (the greater the light transmission, the lower the turbidity) with the B.O.D. curve (Figure 2). Both curves reach their peak during the summer months, which is most fortunate since this is the period during which low stream flow demands the best effluent. It is not to be expected

that the curves shown will duplicate in subsequent years, as the curves are determined to a great extent by the variants in weather, particularly rainfall and sunshine. However, it is fairly certain that, despite such variation, the quality of the effluent will meet the requirements of the stream.

By the use of statistical methods and the data presented from the limited test results (Table II) the following data on the oil content of the fourth basin may be calculated.

$$\bar{X} = 11.25 \qquad R = 16.5$$
$$\sigma = 4.8 \qquad n = 16.0$$

The spread of the data has been exaggerated by the inclusion of the two erroneous samples previously described. Using these data for control purposes, it may be shown that, while in a normal distribution all samples should fall within 3σ above $\bar{X}$, 80 per cent of the samples fell within 1σ. If this ratio holds, or improves as expected, the average will be reduced in future tests. When sufficient samples are run it will be possible to accurately set the upper control limit by statistical methods.

Comparison of Results

Comparison of the new and old systems (Table III) reveals that the system was successfully moved and enlarged and resulted in an improved effluent. In comparing these data, the improvement over the 1950 values in D.O., percent saturation, and B.O.D. is explained by the longer detention time and the better algae activity in the final basin. Color improvement has been gained by virtue of the deeper basins (the old basin averaged about 1 ft. in depth). The cause of the turbidity increase is not known. Since higher dissolved oxygen brought better aerobic action, sulfide odor was practically eliminated and pH rose accordingly. Total alkalinity increased due to additional usage of well water in the plant. Suspended and volatile solids were less, due chiefly to the fact that the deeper basins showed less scouring of the bottom. At the outfall of the old lagoon, the surface of the water was covered with a blanket of duckweed, which occasionally broke loose to increase slightly the suspended solids in the effluent. However, this same duckweed was an excellent filter and was responsible for the lower oil content in the old system effluent. It was planned to seed the new lagoon with this plant, but unfortunately the duckweed was lost during the period of construction. One other item that is responsible for the higher oil content in the new system effluent is the analytical error that was made in weighing several oil samples before the solvent had completely evaporated. More recently, since this error was discovered and corrected, six tests show an average oil content of 7.2 p.p.m., which equals the results of the old system in this particular item.

Table IV shows how closely the effluent from the lagoon averages the composition of the water in the streams. This again is a natural function of the system and nothing has been done to effect such compatibility. The data for Spy Run Creek are for samples taken just above the point of confluence with the Neuhaus Ditch, which carries the lagoon effluent. Note the difference in D.O., which for Spy Run Creek has

TABLE III.—Average Results of Analytical Tests on Final Effluent of Old System (1950) and New System (1953–4)

Item	Old System	New System
Temp. (° F.)	59	54
D.O. (p.p.m.)	3.6	10.5
% Sat.	35.2	99.5
B.O.D. (p.p.m.)	7.4	4.2
Color	Sl. yellow	Clear
Turbidity (% trans.)	96.2	92.0
Odor	Sl. sulfide	Sl. musty
pH	7.43	8.37
Alk., phen. (p.p.m.)	0	23
Alk., m-oragne (p.p.m.)	163	249
Sus. solids (p.p.m.)	19	12
Vol. solids (p.p.m.)	6	5
Oil (p.p.m.)	7.1	11.5

TABLE IV.—Stream Data

Item	Above Outfall	Below Outfall	Spy Run Creek
Temp. (° F.)	47	55	59
D.O. (p.p.m.)	9.2	10.7	3.0
% Sat.	75.9	98.5	30.0
B.O.D. (p.p.m.)	3.7	5.9	4.4
Turbidity (% trans.)	84	87	90
pH	7.88	8.31	7.84
Alk., phenol. (p.p.m.)	0	20	0
Alk., m-orange (p.p.m.)	242	230	297
Susp. Solids (p.p.m.)	22	23	17
Vol. Solids (p.p.m.)	6	9	5
Chlorides (p.p.m.)	40.8	32.6	33.5

been recorded as low as 0.5 p.p.m. However, due to the high D.O. and added flow of the Neuhaus Ditch, the water in the combined streams maintains conditions suitable for fish life. The B.O.D. of the stream below the outfall (5.9 p.p.m.) is 1.2 p.p.m. higher than for the stream above the outfall and is also 1.7 p.p.m. higher than the average for the lagoon effluent. This discrepancy may be due to errors in sampling, but it should be mentioned that several drains from septic tanks discharge to the stream between the two sampling points and are a contributing factor in this discrepancy.

As lagoons regain a place in the treatment field, their application will become more varied and the design problems more critical. Cohn (4) states: "The tendency to look with disdain on lagooning as 'primitive' and 'old fashioned' stems from scientific astigmatism." Derogatory remarks in the past, where justified, have originated from poorly designed and poorly operated systems. This concept of lagoons has eliminated many installations where land was available and the waste was suitable to lagooning. Also, lagooning in too many cases has been considered merely as a temporary detention of a waste until it could be disposed of by dilution, or percolation, with little consideration given to the biological or chemical changes that may change completely the composition of the waste material. Lagooning, while definitely not suitable for all wastes, thus has been indiscriminately removed from consideration without justified or scientific basis.

Lagoons do require considerably more area than other methods of treatment and thus are completely out of the picture for industrial establishments that have no available land. In some cases it has been practical to obtain the necessary acreage—if not adjoining, at least within reasonable distance of the plant. The question arises as to the economical propriety of using land already available and intended for future production facilities for waste treatment lagoons. With proper design to hold the size of the lagoons to the minimum, it may prove a good investment.

The dammed water offers a safety factor against slug contamination that no other system can supply, because dilution alone may reduce to safe limits the concentration of a dangerously toxic waste that may be accidentally discharged. Stream pollution control boards and state and local Boards of Health are not too interested in merely the average results of a system. Even though the effluent may be satisfactory every day of the year but one, fish die but once, so that one incident can be embarrassing to any company. Thus the criteria of waste treatment may be expressed as the poorest operation of a system. Due to the amount of water impounded, the lagoon can absorb, and has absorbed without any damage, accidental loss of soluble oils and other wastes which would have created a shock and potentially toxic load to the creek had the dilution and detention not been available to neutralize the spillage. In Indiana, the state has recently required additional facilities be provided at all plating installations which will eliminate the troubles caused by accidental drainage, breakage, or spillage of cyanide wastes. Experience

has shown that most serious cases of stream pollution from cyanide wastes have occurred from "slug" loads and not from regular rinses or regular processing. Elimination of human failure is most difficult, so insurance against human failure becomes a necessity. Thus the emphasis on prevention of "slug" contamination. What applies to cyanide wastes is equally valid in regards to other toxic wastes. Hence, the advantage of the lagoon in preventing stream damage.

Any plant interested in the re-use of water can appreciate the lagoon as the source of a dependable supply and reservoir. In areas of strained water supply, a lagoon is also a valuable asset as a reserve in case of fire. In the system described facilities have been provided, but are not presently used, to re-use the cooling waters now being discharged. So far it has not been necessary or financially expedient to so use this supply, but it is a dependable reserve if and when additional volume above the present need is required.

Again, comparing the results of the new lagoon system with the original installation, it will be found that the present installation maintains the features of low initial and operating costs, high efficiency, and good flexibility. In addition, one previously described deficiency (low oxygen) of the original lagoon system has been corrected. That leaves only the matter of space requirement and insufficient knowledge of lagoons as demerits to such a system, and both are interdependent on each other. More data are available now and the size of a lagoon may be kept to a minimum to somewhat compensate for this objection. Likewise, as studies are made, such as those conducted by the University of California (2), and supplemented by others, especially in the northern and midwestern states, the remaining objections, if not correctable, may be defined to the point where more accurate decisions can be made as to the value and applicability of lagoons in any prescribed situation.

Acknowledgments

Numerous people, departments, and agencies have been of great assistance during the period covered in this paper. Included are the local and state Boards of Health, the city sewage treatment plant officials, and the various departments and officials within the Dana Corporation.

Special appreciation is due the Plant Engineer and the chemical laboratory staff for their interest and assistance.

References

1. Griffith, C. R., "Purification of Wastes In A Metalworking Plant By Lagooning." *Eng. Bull.*, **35**, 6, 421 (Extension Series No. 76) Purdue Univ. (1951); abs. THIS JOURNAL, **24**, 7, 924 (July, 1952).
2. Silva, P. C., and Papenfuss, G. F., "A Systematic Study of the Algae of Sewage Oxidation Ponds." Publ. No. 7, State Water Poll. Cont. Board, Sacramento, Calif. (1953).
3. Van Heuvelen, W., and Svore, J. H., "Sewage Lagoons in North Dakota." THIS JOURNAL, **26**, 6, 771 (June, 1954).
4. Cohn, M. M., "All Your Eggs In One Lagoon." *Wastes Eng.* **25**, 9, 401 (1954).

FOURTH ANNUAL SOUTHERN WASTE CONFERENCE

Announcement has been made that the Fourth Annual Southern Municipal and Industrial Waste Conference is to be held March 31–April 1, 1955, at the College of Engineering, Duke University, Durham, N. C. This annual conference, organized jointly by Duke University, the University of North Carolina, and North Carolina State College, will feature papers on the general aspects of industrial wastes pollution control, specific industrial waste problems, plant design and plant operation.

DISPOSAL OF WASTE PICKLE LIQUOR BY CONTROLLED OXIDATION AND CONTINUOUS LIME TREATMENT *

By Lorenz W. Heise and Milton Johnson

Respectively, Director of Production Laboratory and Laboratory Supervisor, A. O. Smith Corp., Milwaukee, Wis.

In recent years industry has become more and more aware of the requirements for a positive waste disposal program. Unique to the steel industry is the problem of waste pickle liquor disposal.

"Pickling" is the vernacular expression of the metal fabricating industry for the common method of removing mill scale or iron oxide from the surface of steel. The most universal method of pickling steel is through the use of a sulfuric acid solution. A reaction takes place in the pickling bath as the dilute acid acts upon the iron and iron oxide, causing the release of hydrogen in such a forceful manner that the scale loosens and is subsequently dissolved or readily rinsed from the surface of the steel.

After the pickling bath has been in use for a period of time, the solution becomes saturated with iron salts, making it ineffective and requiring recharging of the bath. The disposal of this waste pickle liquor, containing a large percentage of iron salts and a small percentage of acid, is the essence of the problem.

Releasing the spent liquor into nearby streams, community sewer systems and lagooning areas can result in stream polution, damaged piping, disruption of control at sewage treatment plants, or affect the ground-water system. These consequences are matters of serious concern to everyone and much current engineering effort is being directed toward the elimination of such hazards.

As an example of a typical pickling system, a brief review of the operation at the A. O. Smith Corp. of Milwaukee, Wis. is in order. In this plant, pickling is carried on at a concentration of 5 per cent sulfuric acid, by weight, and at a temperature of 135° F. From time to time acid additions are made to keep the bath up to operating strength. As the iron salt content of the pickling bath increases, the action of the process is retarded. To compensate for the reduced pickling rate, the temperature of the bath is raised to at least 150° F. without the addition of acid.

When the acidity is reduced to 2 per cent or less, the solution is discarded. The specific gravity at this stage will be approximately 1.40 and the ferrous sulfate content, as copperas, approximately 50 per cent by weight. The quantity of waste pickle liquor discarded at this plant varies from 15,000 to 35,000 g.p.d. and averages somewhat more than 5 m.g. per year. The salts in this quantity of waste pickle liquor contain 2,500 tons of iron, which is approximately one week's output of a modern blast furnace. Normally, 15,000 tons of 60° Baumé acid are used per year in this factory.

Consistent with the current trend of developing methods for the proper treatment of industrial wastes, the efforts of this company are concentrated on finding a practical process for the disposal of waste pickle liquor. During the past 20 years, the company has

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

reviewed, studied, or trial tested at least 36 different proposals or methods for the disposal of this waste. Most of these processes were found to be impractical, either operationally or from a high capital investment point of view. Evaluation of the various methods brought a decision to engineer a plant to neutralize the waste pickle liquor with carbide lime, a by-product of the acetylene industry. A neutralization procedure of this type would help to solve two disposal problems in the immediate area—first, the waste pickle liquor and second, carbide sludge from the manufacture of acetylene gas.

Late in 1950, the A. O. Smith Corporation began work on designing a neutralizing plant that would be compact, simple in operation, and low in capital investment cost. Preliminary tests indicated that dewatering of the resultant neutral mixture, formed in the proposed process, would be required for ease of final product disposal. Trial runs using a rotary vacuum filter showed that this type of dewatering would be practical to produce a disposable filter cake. A plant incorporating these ideas was placed in operation in May 1951.

In the process, the waste liquor is gathered from the several pickling locations by stainless steel tank truck and dumped into a receiving vat at the disposal plant site. The carbide by-product lime is moved by a front-end loader from a storage shed and dumped directly into a slurrying tank. The slurry tank is of concrete construction, rectangular in shape, tapered from ground level to a depth of 8 ft. At the ground level side of the tank, located at an outside wall of the main building, a hopper and screen arrangement allows the front-end loader to release the dry lime directly into the tank and prevents foreign material from enter-

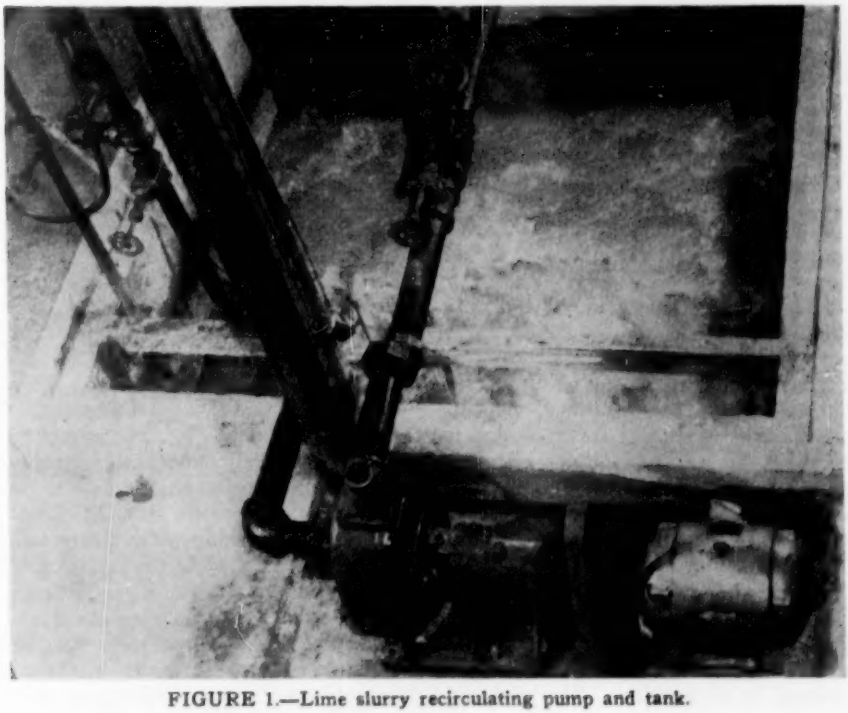


FIGURE 1.—Lime slurry recirculating pump and tank.

FIGURE 2.—Reactor tank (right) and filter (left).

ing the system. A recirculating pump (Figure 1), rated at 400 g.p.m. and operating continuously, slurrys the lime and the constant agitation holds the lime in suspension. A bleed-off from this same hydraulic recirculating system allows whatever lime is required to go to a reactor tank. Slurry tank capacity is approximately 3,000 gal., each gallon containing from 2 to 2.5 lb. of lime.

Through semi-automatic operations, the waste pickle liquor and lime slurry are pumped into the reactor tank in controlled quantities to maintain the mixture at a pH of 7.0 to 8.0. The reactor tank (Figure 2) was designed to allow a 15-min. maximum retention time for chemical reaction. The plant runs at 95 to 98 per cent chemical reaction efficiency.

The lime slurry and waste pickle liquor are admitted continuously to the bottom of the reactor, together with a small amount of compressed air, in such a manner as to be immediately interspersed by an agitator. The trial and error method was used in the selection of the speed and blade design of the agitator to obtain the proper particle size of the neutral precipitate for best filtering results.

Operation of this plant, in the early stages, indicated that the extent of oxidation of the ferrous ions affected filtering rates to a marked degree. Investigation of this phenomenon showed that the best rates were obtained when from 2 to 5 per cent of the ferrous ion was oxidized to the ferric state. The effect of oxidation on filter cake thickness is shown in Figure 3. The discovery of the fact that good filterability was obtained at this low percentage of oxidation was an important factor in making this process unique as well as practicable. To insure that the chemical reaction is taking place under conditions of controlled neutralization and oxidation, use is made of a conductance meter developed in the company's laboratory. Figure 4 shows the results of a series of tests measuring the electrical conductivity of waste pickle liquor with

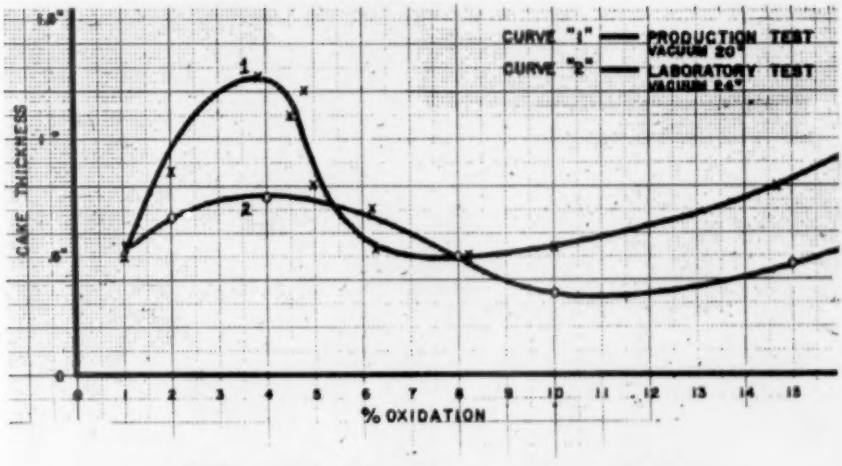


FIGURE 3.—Effect of oxidation on filter cake thickness.

lime added in variable quantities to obtain a range of relative normality values of the resulting mixture. When run at varying temperatures it is noted that the point of lowest conductivity is at a point just past neutral on the alkaline side. This compares with a pH of 7.5. The sharp crest in these curves made it easy to design a practical instrument for measuring the conductivity of the solution and thus maintain a close control of the mixture at the desired pH value.

After retention in the reactor tank, the partially oxidized neutral mixture moves by gravity to the disc-type vacuum filter and subsequently the filter cake, 50 to 60 per cent in moisture content, drops into a hopper (Figure 5). Most of the filtrate is re-used in the lime make-up system and the balance is discharged to the municipal

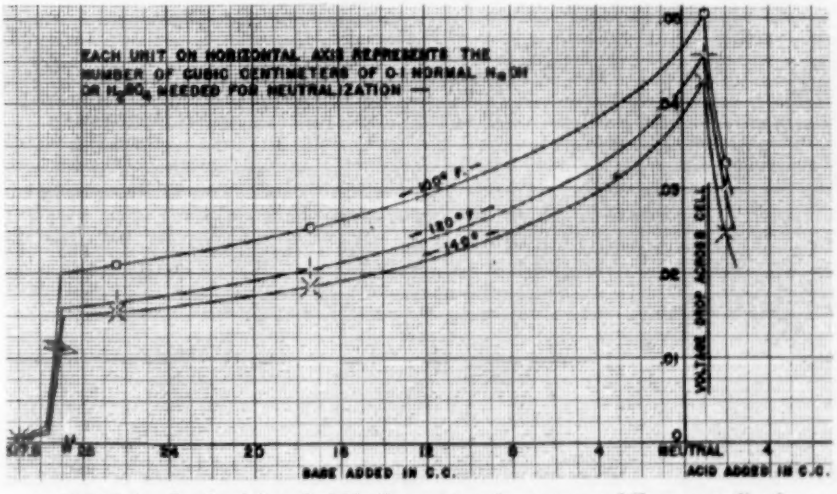

EACH UNIT ON HORIZONTAL AXIS REPRESENTS THE NUMBER OF CUBIC CENTIMETERS OF 0.1 NORMAL NaOH OR H_2SO_4 NEEDED FOR NEUTRALIZATION —
VOLTAGE DROP ACROSS CELL
BASE ADDED IN C.C.
NEUTRAL
ACID ADDED IN C.C.

FIGURE 4.—Conductivity of pickle liquor at various stages of lime neutralization.

FIGURE 5.—Disc filtration of neutral pickle liquor sludge.

sewer. Normal operation results in final disposal of twenty 10-ton truck loads of filter cake each day.

Figure 6 shows a schematic diagram of the controlled oxidation-conductance neutralization process. The waste pickle liquor is collected from the several locations around the plant and

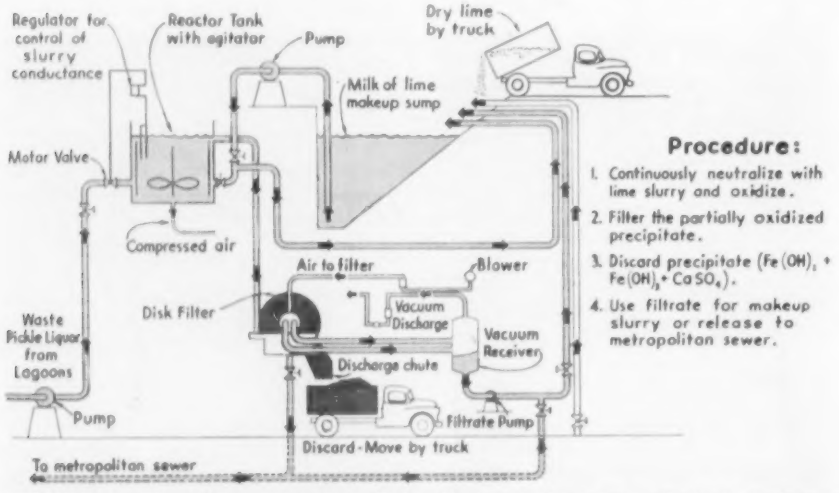


FIGURE 6.—Flow diagram for controlled oxidation-conductance method of continuous neutralization of waste pickle liquor.

placed in an underground storage tank or open lagoon. The lime is brought to the make-up sump and hydraulically slurried. The lime slurry and waste pickle liquor are then brought together in the reactor tank with a small amount of compressed air at a point immediately below the agitating impeller. The resultant chemical reaction is carried on under conditions of controlled oxidation and neutralization by the use of a specially designed conductance meter. The resultant mixture flows by gravity to the vacuum disc filter, where it is partially dewatered and subsequently drops into the loading hopper and dump truck. Most of the filtrate is used as make-up water in the lime sump, the balance being released to metropolitan sewers.

A general view of the complete disposal plant (Figure 7) shows the stainless steel tank truck discharging the waste pickle liquor into the holding basin, the front end loading tractor in the foreground handling the lime, and a truck emerging from the building with a load of filter cake.

Through the method just described, there has been developed an economical low capital investment process for the disposal of waste pickle liquor. However, additional savings would be possible by establishing uses for the by-product. Significant progress has already been made in this direction. During 1954 experiments have been conducted in the use of filter cake as a soil conditioner. Using a small percentage of filter cake additive, data have been gathered showing the effect on fruit yield of tomato plants grown in identical soils except for this addition. The studies reveal that there exists a consistent difference in the fruit yield as shown in Figure 8. Almost 20 per cent more ripe fruit has been obtained from the treated soil compared to the untreated soil during a five-week period.

Similar experiments have been carried on with other plant life and the results have been encouraging. No specific claims are made for application of the filter cake to soil as an aid to plant growth, but it is believed that a

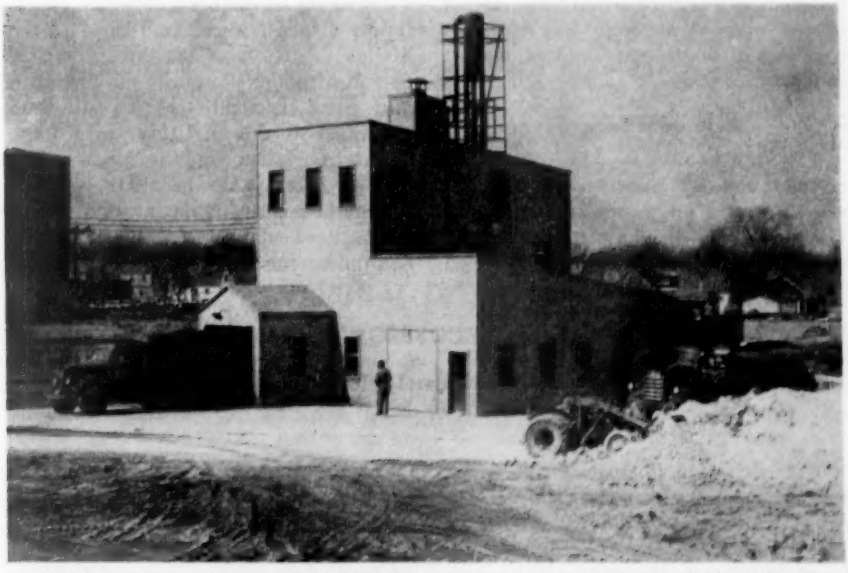


FIGURE 7.—Over-all view of pickle liquor treatment plant showing methods of handling waste pickle liquor (right), carbide lime (foreground), and filter cake (left).

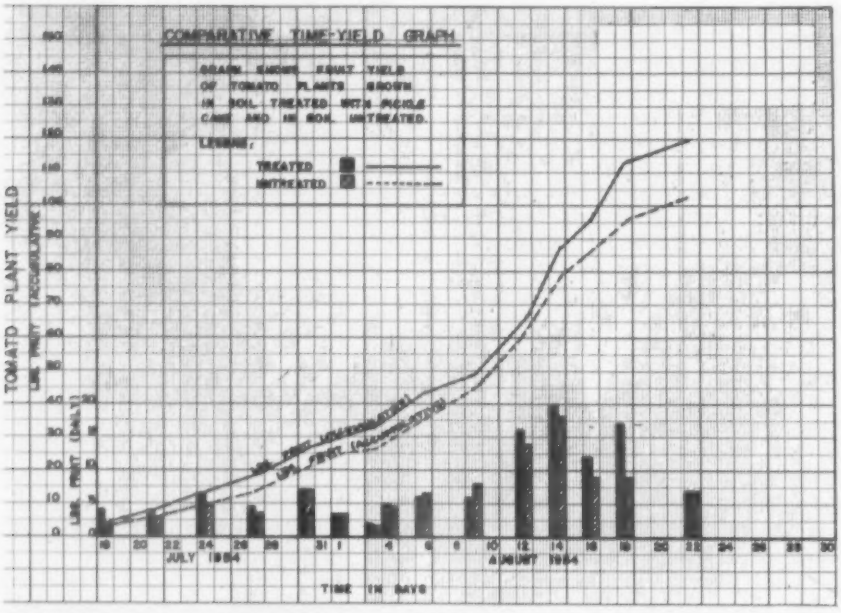


FIGURE 8.—Comparative yields of tomato plants grown in untreated soil and in same soil treated with pickle liquor filter cake.

possible use has been discovered for this material which will greatly assist the steel industry to remove the stigma placed upon it through the resultant products of one specific and important industrial waste.

Acknowledgments

The authors wish to acknowledge the helpful counsel provided at various stages of the process development by Henry Heisig, Chief Chemist, Milwaukee Sewerage Commission, and Richard D. Hoak, Senior Fellow, Mellon Institute of Research. Some earlier developments in methods of waste pickle liquor disposal were established at the Mellon Institute as the out-growth of the Multiple Fellowship of the Iron and Steel Institute which has been sustained at the Institute since 1938.

Patent claims on the process described herein have been allowed and the method is available through Eimco Corp., licensed to engineer and install equipment for this purpose.

DISCUSSION

By Richard D. Hoak

Senior Fellow, Mellon Institute, Pittsburgh, Pa.

The invitation to discuss this paper was accepted with special pleasure because of the interest of the American Iron and Steel Institute Fellowship in pickle liquor disposal, and because the original work which led to the process described was done at Mellon Institute.

For analytical chemists this process illustrates the value of analytical methodology to research on process development. About 10 years ago there was

needed a more rapid method for determining total sulfate than the conventional barium chloride procedure. It was found that when an excess of standard caustic soda is added to pickle liquor and the mixture is boiled briefly, the precipitated ferrous hydrate is converted to ferroso-ferric oxide. This material can be filtered off and the excess caustic titrated to measure the sulfate present. Application of this finding to pickle liquor neutralization provided the basis for the process described.

The observation that ferroso-ferric oxide is formed suggested the necessity for carrying the oxidation far enough to yield this oxide. Ferroso-ferric oxide ($Fe_2O_3 \cdot FeO$) contains two atoms of ferric and one of ferrous iron. Thus a ferric/ferrous ratio of 2:1 appeared to be indicated. A series of runs carried out at various ratios indicated that the actual ratio was not a critical factor because good filterability occurred with ratios in the range 2.5 to 3.5. Filterability became progressively poorer as the degree of oxidation fell further and further outside this range.

The A. O. Smith Corporation installed the first commercial embodiment of the process. In their development work the important discovery was made that oxidation of only 2 to 5 per cent of the iron was adequate to provide a high filtration rate. This was far outside the range of the original work, and it made the process more attractive. One result has been installations at three other industrial locations.

An important feature of the process is the fact that it is not limited to high-calcium lime or the acetylene sludge being used at A. O. Smith. Dolomitic lime has a higher basicity than high-calcium lime, but it is less reactive and produces a bulky sludge in conventional neutralization. In the aeration-neutralization process, however, advantage can be taken of the lower cost per unit of basicity purchased as dolomitic lime. In addition, the sludge volume is only about one-half as great. Dolomitic sludge is not as filterable as high-calcium sludge because the filtration rate is a function of the co-precipitated calcium sulfate. Caustic soda can be used as the neutralizing agent, but its relatively high price is a deterrent. With this reagent the products are hydrated iron oxide and a solution of sodium sulfate. Under special local conditions it might be practical to market sodium sulfate and convert the oxide to a pigment. Ammonia can be used similarly, but the temperature must be held at 75° C. or higher for the process to be operated successfully.

Use of the sludge as a soil supplement is an interesting development. It is to be hoped that investigation of this agricultural use will be continued.

1954 JOURNAL ISSUES NEEDED

An unprecedented increase in Federation membership growth during 1954 has resulted in depletion of the stock of certain 1954 Journal issues. These are urgently needed to fill requests for these issues by libraries and other permanent record facilities throughout the world.

The issues needed are those for February, April, July and October 1954. The Federation is authorized to purchase the listed issues at $0.50 per copy and to reimburse the sender for the necessary postage charges. Send any extra or unwanted copies of these issues to: Federation of Sewage and Industrial Wastes Associations, 325 Illinois Building, Champaign, Ill.

TREATMENT OF MACHINE SHOP WASTES CONTAINING EMULSIFIED OILS *

By C. W. Hathaway

Metallurgical Department, Chevrolet Detroit Forge Division, General Motors Corporation, Detroit, Mich.

This paper deals briefly with the efforts of the Chevrolet Motor Division of General Motors Corporation to reduce the oil content of waste waters at manufacturing plants in several different cities and to render the recovered oil suitable for use as a substitute for purchased oils.

Sources and Characteristics of the Wastes

The waste under discussion is that effluent from machine shop, stamping, and heat treating operations which carries oil in both the free and emulsified forms. The free oil consists of lubricating oils, hydraulic oils, quench oils, etc., which reach the water through leakage or washing operations or, at times, through direct dumping, either intentional or accidental.

The presence of emulsified oils is due to the direct dumping of rancid or dirty cutting and grinding coolants and the washing of either free or emulsified oils from various articles by the use of emulsifying cleaners.

The waste is complex in nature, containing not only the various oils, greases, and drawing compounds, but also the various cleaners that have been used to transfer these materials from the metal pieces to the water. These latter compounds have a definite effect on the ordinarily insoluble oils that are present, often causing them to combine with considerable water. The resulting emulsion has little commercial value when skimmed from the waste. There are often in addition various other incidental pollutants, such as fine grinding debris and other dirt, which may complicate the treatment process.

The waste water may be quite large in volume and, in the Chevrolet plants, has varied in oil content from a few to as high as 40,000 p.p.m.

The extent of treatment applied is dependent upon the quantity of waste involved and the quality of effluent necessary to prevent undue pollution of the receiving sewer or body of water.

Considerable experimental work on the treatment of this waste has been done in the company's laboratories, on pilot-plant set-ups, and in full-scale operations. The results obtained and the treatments used are consistent with the general principles that an emulsion of oil and water may be broken by treatment with an electrolyte and that small quantities of oil may be removed from water by treatment with a coagulating chemical. As observed by others, it has been here determined that an inorganic salt is more efficient than an acid (in similar quantities) and a salt, the positive ion of which is divalent or trivalent, is more efficient than one with a monovalent ion. It has also been observed that a much more complete break can be obtained, if the pH is such that there is a slight amount of floc formed.

Single-Step Process

The simplest process used at Chevrolet is a continuous treatment of segregated waste by the addition of aluminum sulfate. This is used at a plant where the amount of oil waste is not

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

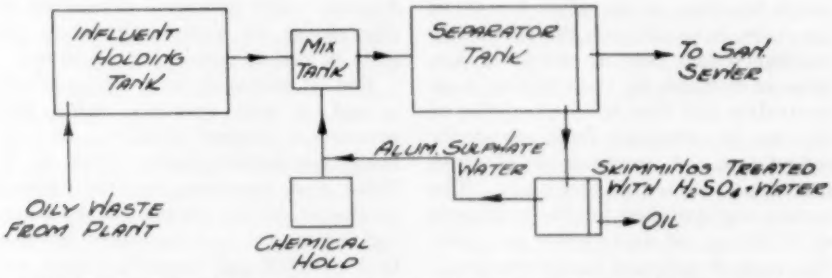


FIGURE 1.—Flow diagram for simple treatment of small flows of oily waste waters.

great and the effluent goes to a sanitary sewer. Non-oily waste from other parts of the factory subject this effluent to considerable dilution.

This treatment produces an oily scum which rises to the surface when the liquid is passed through a small gravity-type separator. The scum is removed and subsequently treated with sulfuric acid and heat. The aluminum hydroxide floc is broken down and aluminum sulfate is re-formed. The oil is released and rises to the surface. The combination of newly formed aluminum sulfate and excess sulfuric acid is used as a treating chemical, as a substitute for, or in combination with the alum in the first stage of the process. This process is outlined in Figure 1.

Two-Step Treatment Involving Sedimentation

The first Chevrolet attempt at large-scale treatment of this type of waste was at a plant where many varieties of machining, grinding, and stamping operations were involved. The effluent was to be discharged to a small river which was subject to considerable pollution from manufacturing industries.

This treatment system (Figure 2),

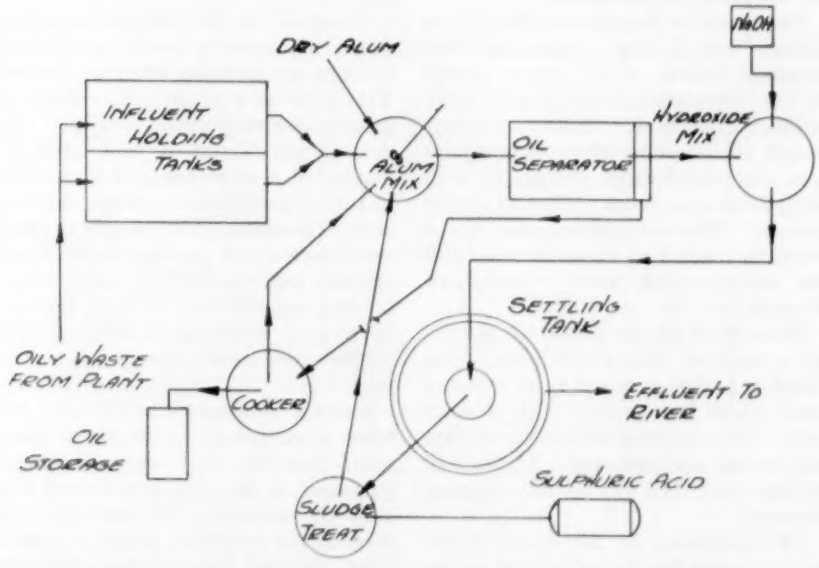


FIGURE 2.—Flow diagram two-step treatment involving sedimentation.

which has been in operation for about six years, is based upon the previously mentioned fact that oil can be broken from an emulsion by the addition of an electrolyte and that small quantities of oil can be removed from water by coagulation. A combination of these treatments is used at this plant. The system was designed for the treatment of 10,000 gal. of waste water per hour. The waste is collected in various sumps located throughout the manufacturing areas. It is then pumped through overhead pipelines to two 64,000-gal. holding tanks on the roof of the treatment plant.

From here it descends through syphons to the first (upflow) mixing tank, where it is treated with a combination of aluminum sulfate and sulfuric acid and subjected to rather rapid agitation for a retention period of about 10 min. It then passes to a gravity oil separator, where the released oil with some floc is skimmed off and routed to a holding tank. The separator is sized for a retention period of about 2 hr. During this operation the pH is about 4. Caustic is next added to raise the pH for optimum floc formation.

The waste is then passed through a mixing tank having a retention time of about 5 min. From here it passes to the coagulation zone of a circular sedimentation tank. This is a conventional combination type of coagulation and clarification equipment with peripheral weir, scum baffle, and sludge scraper. The coagulation zone has a retention period of about 30 min. and the sedimentation zone a period of about 8 hr.

The settled sludge passes by gravity to a vertical cylindrical tank, from which it is then pumped to an elevated tank, where it is treated with sulfuric acid. The resulting aluminum sulfate and excess acid are routed to the first mixing tank for use as the treating chemical.

The treatment of the sludge is resorted to, not for the purpose of saving chemicals, but as a means of sludge disposal. The continual deposition of oily sludge on dumps ultimately results in rather perplexing problems.

The oil skimmed from the separator is not of any economic value and presents a disposal problem. It contains considerable water (often up to 75%) and therefore requires further treatment before re-use. This material is pumped to a lead-lined cooking tank of 2,000-gal. capacity (there are two in this installation). It is here treated with sulfuric acid and heated to about 180° to 200° F. This causes a breaking of the emulsion. A layer of practically water-free oil rises to the top. Below this is a rather heavy combination of oil and water, followed by a lower layer of water, and the excess of sulfuric acid. The lower layers are drawn off and used as a dosing chemical in the first mixing operation. The oil layer is boiled to further reduce the water content to a point where it is not objectionable for the best use of the oil.

The system just described is fairly efficient and reliable. It is subject, however, to certain variables and upsets.

Variation in the composition of the waste may cause a temporary impairment of the emulsion breaking process. This permits a greater oil content to pass to the coagulation process. The greater quantity of oil causes the formation of a more buoyant floc, which in turn is conducive to poorer clarification. Buoyant floc is particularly troublesome in a process where no coagulant aid (such as activated silica) is used, but activated silica is believed to have a detrimental effect on the sludge treatment process previously described.

Another sedimentation difficulty, perhaps more prevalent in waste treatment than in other water treatment processes, is the tendency toward temperature variations. The waste often arrives at the treatment plant at a somewhat elevated temperature. Warmer water entering the sedimentation cham-

ber tends to rise. It may channel upward to the surface in columns, carrying floc through the sludge blanket and toward the effluent weir. Floc that would ordinarily settle quite readily is thus carried over the weir. It is interesting to observe that floc which would not settle in a circular tank with, say, 6-hr. retention will often settle in the weir trough where there is considerable current. This may be due to a variety of factors. One of these is apparently the tendency for a floc particle to lose some of the oil load when the particle strikes the surface of the water or collides with the edge of the weir. Such particles have been observed to rise, lose the oil in a film at the surface, then descend to the lower portions of the tank again.

All of the foregoing peculiarities and conditions plus, no doubt, many more, cause variations in the effluent compositions in this type of treatment.

Improved Design

The next Chevrolet treatment plant was designed with these difficulties in mind. The effluent from this plant is discharged to a storm sewer, which is routed to a small creek. Sudden discharges of an objectionable effluent would be readily noticeable in this type of stream.

The general plan of treatment was similar to that of the system just described, with certain exceptions (see Figure 3). The oil separating capacity in the first stage of the process was doubled. Two skimming tanks were used and these are so elevated and valved that they may be operated either in series or in parallel.

Two sedimentation tanks are provided instead of one. These may be operated either in series or in parallel. The first, of a rectangular, longitudinal flow type, is being tried to reduce the effect of convection currents due to temperature differences. It was thought that these currents would have time to dissipate before the water reaches the effluent weirs located at one end of the tank. Circular tanks of moderate size have such short distances between points of influent and effluent that disturbances in the former are often quickly reflected in the latter.

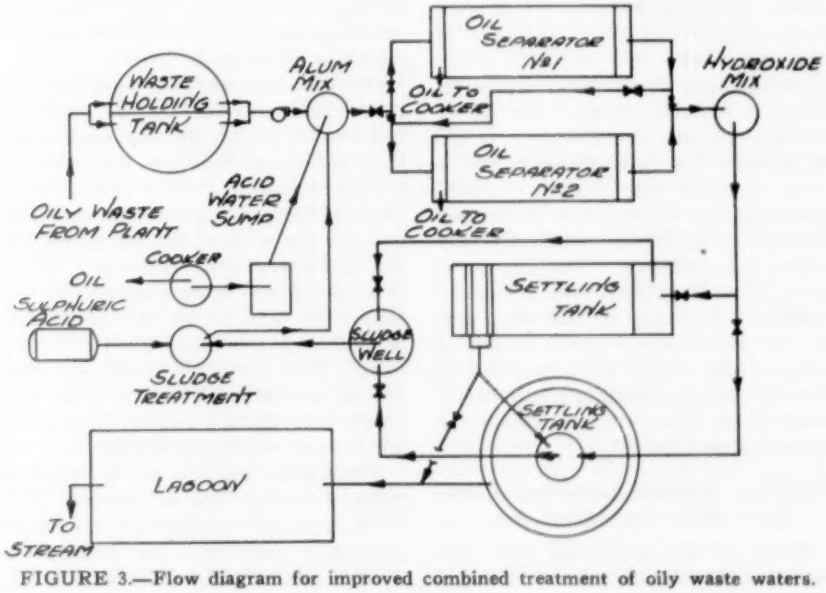


FIGURE 3.—Flow diagram for improved combined treatment of oily waste waters.

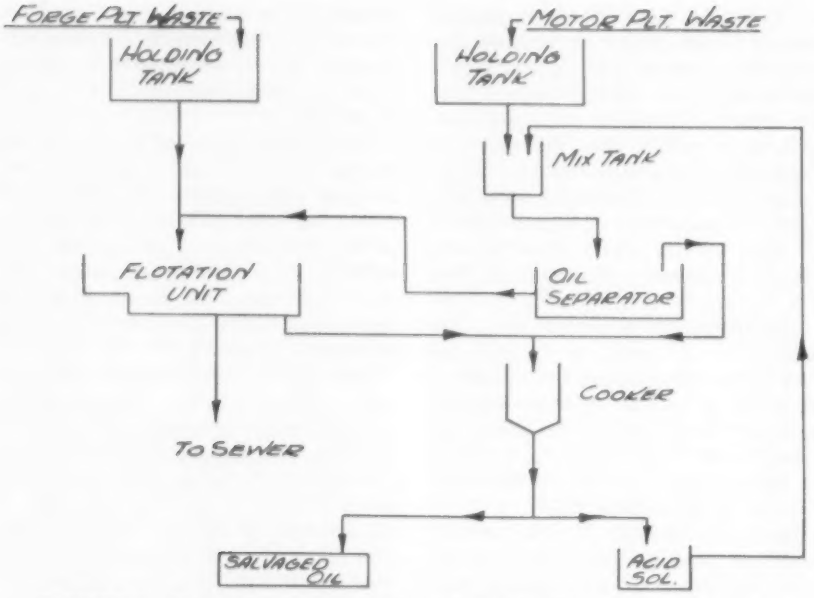


FIGURE 4.—Flow diagram for treatment of combined forge plant and motor plant wastes by flotation units.

The second sedimentation tank is of conventional circular design, except for a rather large sidewall depth for an extra deep sludge blanket. Provision is made for the addition of extra alum at the coagulation zone of either of these two tanks.

The effluent from this system is routed to a small lagoon before being discharged to the storm sewer. It has the capacity for about 45-hr. retention at the designed rate of flow. Assuming operations taking place 16 hr. per day, this would be equivalent to nearly three days retention. The lagoon is designed with outlets just below the surface of the water so that scum will not be discharged. There is also a bottom drain so that the lagoon can be drained during periods of heavy runoff or at times when ice might clog the surface effluent lines.

Two-Step Process Involving Flotation With the Aid of Air

Before the last mentioned plant was put into operation it became necessary to design two more systems. One of these was for the treatment of a typical machine shop oily waste. It was comparatively small in size and presented an opportunity for a rather thorough investigation of one of the popular dissolved air flotation units.

Provision was made for a preliminary treatment involving chemical addition, followed by simple gravity separation, then additional chemical treatment in a dissolved air unit. This arrangement yielded fairly consistent results without the use of final filters, which are now becoming quite common. While this system was being constructed, design work was begun on the largest treatment system undertaken by Chevrolet. This system is being provided for the treatment of wastes from two plants—an engine manufacturing plant and a forge plant (see Figure 4).

The engine plant waste is expected to have a rather high oil content. It is to be given the preliminary treatment previously mentioned for removal of most of the oil. The effluent from this

treatment will then join the forge plant waste, which is greater in volume but lower in oil content. This combined waste is then subjected to the dissolved air flotation treatment. All skimmings are to be treated in cookers as previously described.

The effluent joins non-oily effluents from these plants and from a large foundry before passing to the river.

All of the flow sheets shown are extremely elementary. These plants are rather elaborate in respect to both piping and housing. Spare pumps, bypasses, and emergency overflows are provided wherever possible. The buildings are of factory-type brick and concrete construction. Most tanks are of steel, with acid-resistant linings where necessary.

The systems described are expensive to build and expensive to operate, the value of the recovered oil only partly paying the cost of operation. All except the last system described have been in use for some time. They have been effective in controlling pollution at their respective locations. The amount of oil removed from the water over a period of time is rather startling, more than 2,000,000 gal. having been reclaimed since 1950. Most of this has been used as a fuel oil, with about 100,000 gal. used in dust control operations and 60,000 gal. in polishing operations.

DISCUSSION

By T. R. Haseltine

Partner, The Chester Engineers, Pittsburgh, Pa.

It is obvious that Mr. Hathaway and his organization have had wide experience in both the laboratory research which must precede the design of plants handling oil emulsions, and also in the actual operating performance of such plants. Although the writer's firm has long been interested in the treatment of the so-called "soluble oils," its operating experience has been far less extensive and therefore it is with considerable temerity that an attempt is made to discuss this interesting paper.

The comparative lack of experience is due in part to the fact that many of the firm's clients having a soluble oil problem also have a pickle liquor problem. Wherever the two wastes are encountered in the same plant, they may best be disposed of together. No additional chemicals are required and the resulting sludge is far less voluminous than would result from the separate treatment of the two wastes.

In the Pittsburgh area a separate company, known as Industrial Wastes, Inc., has developed a thriving business in the collection of spent pickle liquor from various industries and the treatment of such liquor in central plants (1). The charge for such service ranges from $0.02 to $0.025 per gallon. Many industries find that service to be the most economical way of disposing of spent coolants or similar emulsions of relatively high oil content. By the adoption of various good housekeeping procedures within the machine shops, they have greatly reduced the chance for the contamination of otherwise clean cooling water with either coolant or non-soluble cutting and quenching oils. Illustrative of such procedures is the use of double-compartment boxes and bins, by one concern, for the collection and temporary storage of metal chips and cuttings. The two compartments are separated by a perforated false bottom. The content of the lower compartment is periodically dumped to the spent pickle liquor storage reservoir.

Obviously no industry can afford to spend $0.02 or more, per gallon to dis-

pose of relatively large volumes of low oil content emulsions. However, experience to date indicates that if such wastes are combined with rinses from acid pickling and alkaline cleaning operations, the mixed wastes can be effectively treated in simple basins equipped with mechanical skimming and sludge removal facilities of conventional design. The control of pH is only necessary where the volume of pickle liquor rinse is far in excess of the other wastes.

Analyses at one such basin, which was designed for a theoretical detention period of 1.7 hr. and a settling rate of 650 g.p.d. per square foot, indicated the following when operating at about 30 per cent of design capacity:

Determination	Influent	Effluent	Reduction (%)
pH	5.4	5.25	—
Suspended solids (p.p.m.)	7,365	1,035	85.9
Oil and grease (p.p.m.)	187	12	93.6

Sludge is pumped from the basin about twice a week and combined with the spent pickle liquor for ultimate disposal by the waste collection company. Normally, very little scum forms on the tank surface, however exceptions are frequent enough to justify the provision for mechanical skimming. The scum is also combined with the spent pickle liquor.

Where pickling wastes are not available, the separate treatment of oily wastes is far more difficult. Apparently such is the case at the plants described by Mr. Hathaway. Several years ago the writer pointed out the wide variation in the characteristics and treatability of various soluble oil emulsions (2). Mr. Hathaway calls attention to the other variables introduced into such wastes due to the admixture of other oils, greases, cleaners, drawing compounds, grinding debris, dirt, etc. He also mentions the effect of temperature changes. In the light of these many changeable conditions, it is not surprising that Chevrolet has used several different flow diagrams and that other concerns have adopted still different plans (3). However, the prevalence of these many variables points to the following conclusions:

1. Any sedimentation unit provided for the treatment of oily wastes should be equipped with effective skimming devices.

2. Any flotation unit provided for the treatment of oily wastes should have adequate provision for sludge removal.

3. The first unit of any oily waste treatment plant should be a large receiving and equalizing well—the larger the better.

If wastes from heat treating operations are to be included, the installation of cooling coils in the well and provision for recirculating its content should be carefully considered.

The use of multiple separators and settling tanks arranged for either series or parallel operation, as illustrated by Figure 3, adds greatly to the cost and complexity of the plant and would require very intelligent operation to realize its benefits. The use of a larger waste holding tank equipped with adequate cooling coils and recirculation facilities might have permitted the use of a simpler plant of equal or less initial cost.

The ability to recover a usable oil from the treatment of the machine shop emulsions sounds attractive but, as stated by Mr. Hathaway, the value of the recovered oil is insufficient to pay the cost of operation. Its recovery adds appreciably to the cost of constructing and operating the plant. There may be many instances where the use of cheaper and less complicated processes would be warranted even though they failed to recover any oil whatsoever.

The writer has often wondered why so many soluble oil treatment plants utilized the two-stage process, wherein

the wastes are first acidified and treated by gravity oil separation after which alkali and coagulant are added for final treatment by sedimentation or flotation. A simpler single-stage process involving only coagulation, followed by sedimentation or flotation, would produce an effluent of equal quality in a smaller, simpler, and cheaper plant. Less alkali and no acid would be required. True, it would be necessary to use some more alum or other coagulant, due to the higher oil content of the wastes being coagulated. However, experience indicates that as long as the oil content of the initial waste does not exceed 3 to 4 per cent, a 50 per cent reduction in its oil content will effect something less than a 20 per cent saving in coagulant requirement. Furthermore, it should be noted that some emulsions can not be broken by acidification, even to a pH of 2 or less.

Many of the wastes contain free floating oil as well as emulsified oil. The free oil should be removed in advance of coagulation. However, provisions for such removal could be incorporated in the holding and equalizing tank, thus eliminating the need for the first-stage separators.

In all of the plants described by Mr. Hathaway, the sludge resulting from the coagulation process is acidified to permit the recovery of aluminum sulfate. However, he states that this method of sludge treatment has been adopted primarily as a means of sludge disposal. Personal experience corroborates the fact that the continual disposition of oily sludge on dumps may ultimately result in rather perplexing problems. However, much depends upon the location and arrangement of the dump or lagoon. Furthermore, there are some instances where small volumes of spent coolant are simply disposed of by dumping over coal storage piles. Perhaps a similar disposition of sludges would be adequate in some instances.

The acid treatment of the sludge as described by the author does, of course, effect some saving in alum requirements. However, it necessitates the purchase of acid, materially increases the amount of alkali needed, and adds greatly to the complexity of the plant and its operation. There must be many instances where the trucking of sludge to suitable dumps would be warranted by the saving in initial plant cost and simplification of operation.

It is regretted that Mr. Hathaway did not discuss the relative merits of air flotation and sedimentation devices. Experience with laboratory-size air flotation units indicate that, for the same waste, flotation requires about 40 per cent less coagulant and produces a scum of materially less volume than that of the sludge resulting from sedimentation. Beebe (3) has pointed out the economy of space resulting from the use of air flotation. Despite lack of personal full-scale operating experience with such units, the writer ventures the opinion that they are far less affected by temperature changes than are sedimentation basins.

References

1. Harper, J. H., "Central Treatment Plant for Waste Pickle Liquor." THIS JOURNAL, **24**, 80, (Jan., 1952).
2. Haseltine, T. R., "Character and Treatment of Soluble Oil Wastes." *Sewage Works Jour.* **21**, 5, 859 (Sept., 1949).
3. Beebe, A. H., "Soluble Oil Waste Treatment by Pressure Flotation." THIS JOURNAL, **25**, 11, 1314 (Nov., 1953).

OPERATION OF ION EXCHANGE UNITS FOR TREATMENT OF ELECTROPLATING WASTES *

By T. J. Fadgen

Chemist and Metallurgist, Ternstedt Division, General Motors Corp., Trenton, N. J.

The management of the Ternstedt Division of General Motors Corporation has always been keenly interested in the problem of water conservation. At the same time, it has had the equal conviction that pollution abatement and water conservation were combined rather than separate objectives. Because of this belief, approval was given for the construction of an ion exchange pilot unit at the division's Trenton, N. J. plant. Prior research had indicated that ion exchange offered one logical approach to the solution of the twin problems of water conservation and pollution abatement.

The waters selected for treatment were those discharged from rinsing operations following chromium, nickel, and acid copper electroplating operations. Each type of rinse water is handled separately and given a complete demineralization treatment by passing through a cation and anion exchanger. Effluent water of this quality could be used for a wide variety of in-plant operations.

The ion exchange units were built to the company's specifications, which had been developed as the result of several years of research work upon a variety of plating rinse waters. The total quantity of resins installed in the pilot plant is 76 cu. ft. Operations were started in December 1953. Between then and October 1954, 7 m.g. of rinse waters have been treated, reclaimed, and returned to the plant. In general, the results have been good; as a result, a full-scale ion exchange plant is now being constructed at the Flint, Mich., plant of the Ternstedt Division. This plant will have a combined resin capacity of 1,100 cu. ft.

Procedure

The nickel, which is removed from the cation tower as nickel sulfate, is returned to the plating conveyors. Despite predictions, this has not caused any plating difficulties in any manner.

As the reclaimed nickel sulfate has also an excess of sulfuric acid, this excess acid must be neutralized. This is accomplished by using nickel carbonate, which is converted to nickel sulfate by chemical action. The end point for this reaction is a pH of 2.6 to 3.0.

These daily additions of reclaimed nickel sulfate can be made only if it is regarded as an addition in lieu of water. Each conveyor requires daily additions of water in excess of the volume of nickel sulfate solution produced by the ion exchange units.

Acid copper or copper sulfate electroplating solution tends to develop an excess concentration of copper sulfate. Therefore, the copper sulfate from ion exchange recovery has little or no value. However, this same plating process requires considerable daily additions of sulfuric acid. Therefore, the copper sulfate-sulfuric acid combination produced by regeneration of the cation resin is returned to the plating solution in lieu of normal acid additions.

The sodium hydroxide and its added

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

dissolved anions from the 410 resin regeneration are discharged to the sewer system. Studies are being made to develop uses for this discharge in some manufacturing process.

The chromium is removed from the anion resin as sodium chromate, which in turn is treated with barium hydroxide to precipitate barium chromate. This method, rather than reconversion to chromic acid by ion exchange, was selected on the basis of operating economics and the availability of sales outlets for waste chemicals. None of the barium chromate has been sold to date; therefore, a complete evaluation cannot be made.

Resin Performance

There is no indication that the performance level of the resins has altered during the 10-month operating period. Undoubtedly, there has been some loss of resin by carry-off and erosion, but until the cells are opened and a close examination made, the extent of such loss can only be regarded as negligible. At any rate, the general average of through-put gallons to exhaustion has remained relatively constant.

Reclaimed Water

The water reclaimed by ion exchange at the Trenton plant is pumped directly into the steam condensate return lines to the powerhouse. Initially, it was not considered advisable to return this water to electroplating operations until an accurate picture was obtained as to water quality and the probability of introducing undesirable metallics into plating solutions because of mechanical or operator failures at the ion exchange plant. At the Flint plant, the water is to be returned directly to plant process applications.

The established standard for water quality to the powerhouse or resin exhaustion point is a maximum of 4 p.p.m. of calcium carbonate hardness from the cation cell, and a maximum of 15 p.p.m. as SO_4 from the anion bed.

Operating Cost

The cost of operating an ion exchange unit is composed of many factors. A change in the yardstick by which the resin exhaustion point is measured can conceivably alter the through-put volume by as much as 10,000 gal. Changes in technique, concentrations, or cell construction can sharply alter the dollar picture. The strict cook book recipe for operation of the system has built into it many individual's conception of safety factors which only close, interested, and attentive study can evaluate. The prescribed regeneration concentrations and flow rates are established so that the resin equipment will perform as scheduled. However, the objective from the user's standpoint should always be to secure the maximum of performance per dollar of expenditure. If this is recognized, it will be found that this objective is sometimes reached by treatments or practice at variance with the strict laboratory recommendations.

During the period the plant has been in operation, work has been concentrated primarily on regeneration techniques and concentrations and operations have been developed that differ from the initial practices. The following cost comparison is made between actual performance for the 10-month period and what it would have been had there been strict adherence to normal procedures:

Item	Operational Method	
	Actual	Normal
Rinse water treated (gal.)	6,000,000	6,000,000
Cost of regen. chem. ($)	2,438.50	3,899.94

The data are given simply to indicate that the cost as well as the chemistry aspects of ion exchange must be studied. The effect of close attention to techniques and operational mechanics upon the cost of regenerating the resin beds are indicated, the "normal" tabulation indicating what the chemicals cost

would have been had no study been made of means by which this item of cost might be reduced without affecting the performance of the resins.

The cost for ion exchange unit operation will differ from plant to plant. It is affected by such factors as local water quality, the level of the plant process control and knowledge, the quality of the personnel operating the ion exchange units, and the destined use for the demineralized effluent. All these points must be carefully considered before an operating cost evaluation can be made.

Summary

Waste treatment starts with waste prevention. The necessity for any type of treatment should be kept at a minimum by attacking the problem at its source.

Ion exchange for the treatment of electroplating wastes is in its infancy. Although it cannot conceivably supplant all other methods of wastes treatment, it does appear to have an excellent opportunity to accomplish the objectives of pollution abatement, reclaiming process chemicals for further use and conserving process water.

OHIO VALLEY ABATEMENT PROGRAM REPORT

Sewage facilities to treat the wastes from more than 4,000,000 people are now in operation in the Ohio Valley. And new facilities under construction or approved for an early start on construction will treat the sewage from another 3,260,000 people. This is part of the picture on pollution control developments revealed in the sixth Annual Report of the Ohio River Valley Water Sanitation Commission recently presented to the governors of the eight states who are joined in a regional campaign to secure clean streams.

Summarizing accomplishments in the 155,000-sq. mi. area of Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia that constitute the interstate drainage district, the report shows that 45 per cent of the population now is served by sewage treatment, 9 per cent has treatment plants under construction and 26 per cent has plans approved for construction. Sewered population in the district is 9,322,000.

Since the establishment of the Commission in 1948 the rate of increase in the installation of sewage treatment plants has been four times faster than was the case in the same period prior to its formation.

Progress in industrial waste control is revealed from an analysis of reports from the signatory states, which shows that of the 1,190 industries discharging directly into streams of the district, 361 (30 per cent) are rated as adequate; 429 (36 per cent) provide some form of control but more will be required; 32 new installations are under construction; and 129 new facilities are in the planning stage.

Equally important is the reduction of pollution loads from thousands of industries that discharge into municipal sewer systems where treatment plants have been built. For example, there are some 1,800 industries in Cincinnati, the wastes from which will be treated along with domestic sewage.

DISSOLVED AIR RECOVERY OF SUSPENDED SOLIDS

By Joseph Osterman

Project Engineer, Bulkley, Dunton Processes, Inc., New York, N. Y.

In industry today, there is a great deal of talk about cross-fertilization of ideas. Oftentimes, a good idea or a process which has found wide and successful use in one industry can be readily adapted to other industries with great advantage.

Such an idea, the use of dissolved air to separate solids from liquids, or to separate oil and grease from water, is now finding application in a wide range of industries from chemical processing to meat packing—in situations where stream pollution must be avoided or valuable raw materials recovered from process waters. Only a few short years ago, the process was designed for use in paper mills to recover valuable pulp and other ingredients from white water effluent.

Then, after considerable experimentation and development, an advanced process * began finding use for cleaning up waste waters from oil refineries, oil fields, soap plants, meat packing plants, airplane manufacturing plants, and general machining operations. The range of application was made possible by the fact that besides removing suspended material, the process could be adapted to recover colloidal materials such as oil and carbon.

Today, the list of industries and plants that have adopted the process to wage a war on waste and inefficiency, or to steer clear of stream pollution, or both, is growing rapidly. The reason: alert managements are becoming aware that it is smarter and cheaper to police oneself on stream pollution than to become involved in complicated wrangles with regulatory authorities. Also, if valuable raw materials or by-products are being discarded in the effluent, money is being thrown down the river.

The secret of the unit's success is the dissolved air technique, which permits quiescent and efficient performance. Before dissolved air, diffused air systems were used for the same purpose. But such processes were subject to turbulence, frothing and a low density float, none of which occur with the dissolved air process. In the new system, air is introduced into the flow and dissolved under pressure greater than 25 p.s.i. When the pressure is released, bubbles rise to the surface, with more efficient separation, especially with colloidal materials, being achieved by introduction of chemical coagulants into the system. This permits separation efficiencies higher than other systems and at the minimum cost.

Among the primary features of the unit (Figure 1) are its minimum space requirements, low operating depth, and open tank design, permitting installation within buildings and structures at any floor level. Outdoor installations are also practical in many cases.

In most installations, waste effluent flows from the process to a collecting basin or tank of suitable dimensions. From this point, it is pumped through a flow control valve to a closed retention tank (Figure 2), which is divided into two sections by a vertical baffle plate. The functions of this tank are to insure air saturation, to complete flocculation, and to remove excess air. This excess air is released and bled from the closed tank as the water passes over the baffle. At the same time, the desired pressure is maintained regardless of flow variations by an

* The Colloidair process, developed by Bulkley, Dunton Processes, Inc., New York, N. Y.

automatic air-operated control valve at the separator inlet.

Next, the flow from the pressure control valve is passed into a degasification and stilling chamber and is distributed across the top of the inlet section of the flotation tank at a predetermined level. From the time the white water leaves the control valve, all process steps are visible; that is, chemical flocculation, degasification, particle separation (or grease collection), suspensoid float collection, positive removal and compaction of the float mat on the recovery apron, and discharge of the clarified effluent.

Flotation is accomplished by release of the air from solution in water and its physical attachment to the flocculated particles. The buoyancy of the minute air bubbles has the effect of lowering the specific gravity of these particles and conveying them to the surface of the flotation tank. This occurs over the entire area of the flotation tank, resulting in non-turbulent uniform flotation. The equipment maintenance problems encountered in vacuum de-aeration procedures are avoided through pressure dissolving of the air, since ultimate leakage of the air to the atmosphere is the desired

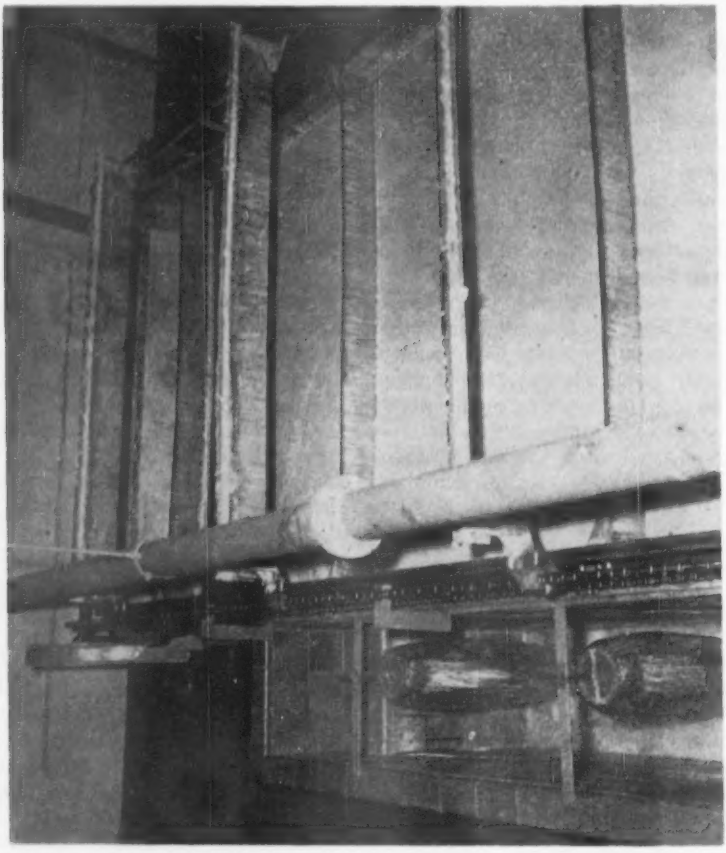


FIGURE 1.—Skimming flights deliver recovered fibers up dewatering ramp for discharge in the recovery chamber (far end). Clarified water discharge chamber (left) has selective telescopic outlets.

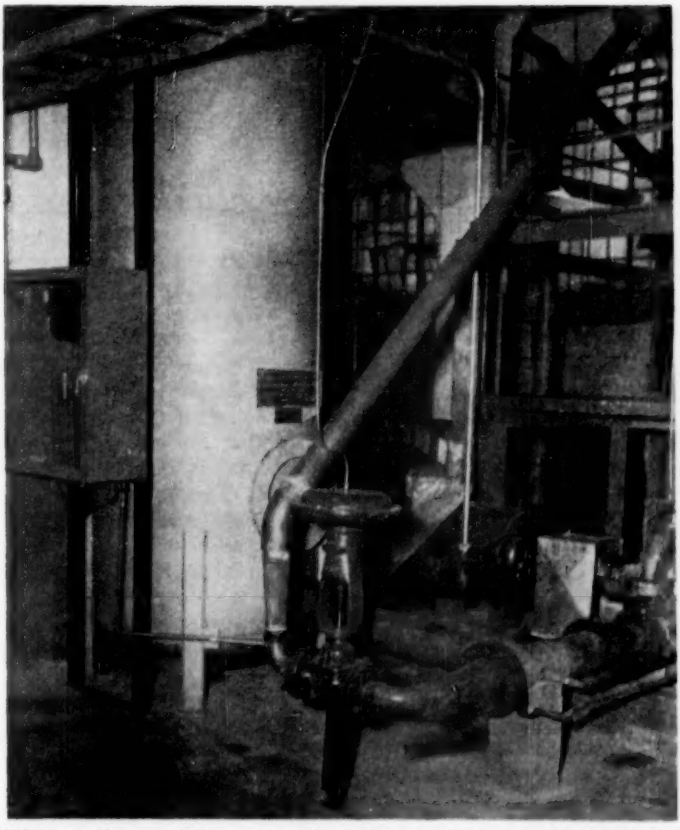


FIGURE 2.—Excess air is removed from the system in retention tank (center). Simple control panel (left) houses all instrumentation and controls.

effect. The entire process occurs in a treatment cycle of approximately 20 min. in most applications, as opposed to 1 to 4 hr. required for other methods of clarification. The net result is a reduction in floor area requirements which today represents a cost of from $0.50 to $2.00 per square foot.

Grease and solids floated to the surface are continuously pushed by flight scrapers towards the recovery trough at the far end of the separator. The adjusted scrapers do not dip into the body of the liquid; thus the liquid is not disturbed. Sludge is collected in the recovery chamber and periodically removed.

Clarified effluent is continuously removed from the bottom of the flotation chamber through uniformly-spaced recovery tubes with adjustable height risers. Effluent discharges into the collection trough for re-use or disposal.

In many cases the recovery of valuable raw materials or by-products from process effluents permits the unit to pay for itself in less than a full year's operation. In other cases, the avoidance of penalties or sanctions for stream pollution violations or the avoidance of a bad reputation make it well worth while to find out if dissolved air can solve your waste water problem.

Stream Pollution

STATISTICAL ANALYSIS OF COLIFORM DATA*

By Harold A. Thomas, Jr.

Associate Professor of Sanitary Engineering, Division of Applied Science, Harvard University, Cambridge, Mass.

Measurements of the density of coliform bacteria have interpretative value in the analysis of problems of disposal of liquid wastes primarily because coliform die-away rates closely parallel those of such enteric pathogens as *Salmonella*, *Shigella*, etc. In a wide range of natural environments, and in disinfection and other artificial treatments, the probability of the survival of the pathogens may be estimated from observations of the density of the coliform group. Kehr and Butterfield (1) showed that the relative densities of coliform and *S. typhosa* in streams depend mainly upon the typhoid morbidity case rate in the drainage area; temperature, dilution, and biochemical activity were found to have a relatively minor influence upon the ratio of the densities of the survivors. A quantitative expression of this relation is as follows:

$$S.\ typhosa \text{ per } 10^6 \text{ coliform} = 3 \times (\text{typhoid cases per } 10^5 \text{ persons per year})^{0.46} \quad . . (1)$$

They also offered evidence that typhoid will be produced in roughly 1 per cent of persons ingesting a single *S. typhosa* bacterium.

Precise evaluation of coliform density is limited inherently by the necessarily small size of samples that can be processed bacteriologically at any one time. The difficulty may be overcome only by averaging the results of many individual density measurements from samples collected periodically from a fixed sampling station. The value of the outcome of this approach depends rather critically upon the method of statistical analysis employed. Many of the averaging procedures that have been used are invalid and give incorrect and misleading results; other methods lead to numerical answers that are difficult to interpret in a meaningful way.

The purposes herein are the following:

1. To show that the arithmetic mean density of a time series of coliform density determinations is superior to other commonly used averages, such as the geometric mean and the median, as a measure of health hazards associated with the pathogenic *Enterobacteriaceae*.

2. To outline proper calculation procedures for estimation of the arithmetic mean density. These procedures are seemingly less direct than the common procedure for computing arithmetic mean, which will be shown to be inapplicable to the purpose at hand. It will also be demonstrated that the arithmetic mean usually is considerably larger than the median and the geometric mean.

3. To set forth the principles of design of coliform water quality-control standards applicable to treatment plant effluents and to streams; to indicate the requirements of a rational and workable set of coliform regulations.

* Presented at 1954 Annual Meeting, New England Sewage and Industrial Wastes Assn.; Fairfield, Conn.; Oct. 28, 1954.

Methods of Estimating Coliform Density

Various techniques are used in measuring the concentration of coliform bacteria. These may be classified as follows:

1. Fermentation tube tests (presumptive, confirmed, and completed).
   a) Single dilution test (common in waterworks practice).
   b) Multi-dilution test (used in analysis of sewage treatment, polluted streams, shellfish, irrigation water, bathing waters, and milk).
2. Membrane filters (in developmental stage).
3. Direct plate-culture methods.

A method of statistical analysis of the single dilution test has been described (2).

At present, there are insufficient data relating to coliform recovery on membrane filters with media of various types and with a variety of waters upon which to base a satisfactory analysis. Some results of preliminary computations have been summarized (3).

Various techniques for the culture of coliform bacteria on Petri dishes have been proposed. Depending upon the type of inhibitory media employed, these yield imperfect degrees of coliform recovery and have not achieved the status of the standard procedures. Despite this failing, however, they possess inherent advantages of precision and simplicity as to merit a definite place in the tool kit of the stream analyst. Further development of direct coliform plating techniques is needed. The mathematical treatment of plate count results is closely similar to that applicable to the membrane filter.

The discussion presented herewith pertains to the multi-dilution test—a series of three or more decimal dilutions with 3, 5, etc., tubes in each dilution. The result of each test may be characterized by the most probable number (M.P.N.) (7). The following sections relate to the proper manipulation of the M.P.N.'s of a series of successive samples from any fixed sampling point.

Generally speaking, the mean coliform density cannot be obtained by a simple arithmetic averaging of the M.P.N. values. Estimates based on such computations may grossly underestimate the true density. There are two reasons for this: (a) Some of the M.P.N. values are apt to be indeterminate, as is the case when all tubes are positive or all are negative; and (b) the M.P.N. of the fermentation tube test is a biased estimator of the true density (7), and the amount of bias depends upon the number of tubes tested in each dilution. Consequently, a factor must be applied to correct for this bias.

Both of these difficulties may be overcome by a procedure based on the plotting of the M.P.N. values on log-probability paper.

The Log-Normal Frequency Distribution

The temporal fluctuations in bacterial density in a polluted stream or treatment plant effluent due to vagaries in climate, runoff, and natural and plant purification processes may be described concisely with reference to the log-normal frequency distribution (4).*

$$f(X) = \left[\frac{0.434}{\sqrt{2\pi}\ (\log \sigma_g)\ X} \right] e^{Z} \quad . . (2a)$$

in which

$$Z = -\frac{\log^2 (X/m_g)}{2 \log^2 \sigma_g} \quad . . . . . (2b)$$

X = the temporary value of the bacterial density (that is, the density at a particular time);
$f(X)$ = the relative frequency of occurrence of any X;
m_g = the geometric mean of X (in this distribution the geo-

* Common logarithms are used throughout.

metric mean and the median, X_{50}, are identical, or $m_g = X_{50}$); and

σ_g = the geometric standard deviation ($\log \sigma_g$ is the standard deviation of $\log X$).

e = base of Napierian logarithms.

The parameters, m_g and σ_g, of the log-normal distribution applicable to any series of M.P.N. values may easily be evaluated by plotting the data on log-probability paper, which linearizes a graph of the integral of the right-hand side of Eq. 2*a* (Figure 1). The plotting position of each M.P.N. on the probability scale may be calculated from the formula

$$F = \frac{100\,i}{N+1} \quad \ldots\ldots\ldots (3)$$

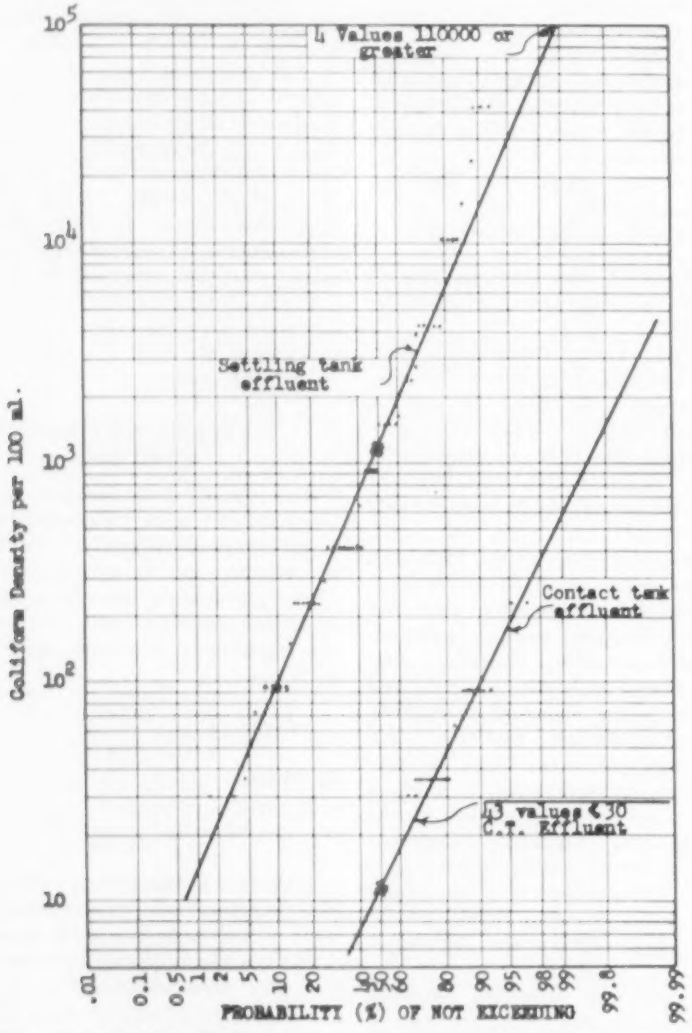


FIGURE 1.—Log-probability plot (5) indicating coliform densities in effluents of the settling tank and chlorine contact tank, Traverse City, Mich., 1949.

where F is the percent probability (that is, the plotting position for the ith M.P.N. value, starting with the smallest); and N is the number of M.P.N.'s in the series, including indeterminate results. Thus, if there are 19 M.P.N. values in the series, the smallest ($i = 1$) would be plotted at 5 per cent, the second ($i = 2$) at 10 per cent, etc.; the largest M.P.N. ($i = N$) would be plotted at 95 per cent. Indeterminate results cannot be plotted, but their existence should be indicated, as in Figure 1. In the common method of computing the arithmetic mean, these tests are neglected or otherwise approximated by the nearest determinant M.P.N. in the table. By either procedure large errors are likely to be introduced, since indeterminant tests are apt to occur when the true density is extraordinarily high or low. With the use of log-probability paper, however, account is taken of indeterminant results in the evaluation of the plotting positions of the determinant M.P.N.'s.

From a straight line drawn through the plotted points, the median value (50 per cent quantile), m_g, may be read directly from the graph. The 84 per cent quantile, X_{84}, also may be read. With these two quantiles the geometric standard deviation may be calculated by the relation $\sigma_g = X_{84}/m_g$.

Finally, the arithmetic mean density, m, may be calculated from*

$$m = C\, m_g\, \sigma_g^{1.15 \log \sigma_g} \quad \ldots\ldots (4)$$

where C, a factor correcting for the bias of the M.P.N. as an estimator of the true density, depends on the number of tubes, n, used in each dilution and

$$C = e^{-0.805/n} \quad \ldots\ldots (5)$$

The following are values of C for common values of n:

n	3	5	10
C	0.764	0.851	0.922

Values of σ_g for sewage plant effluent and stream coliform data range from 3 to 25. With large values of σ_g the arithmetic mean greatly exceeds the geometric mean or median.

* The derivation of Eq. 4 is presented in the Appendix.

TABLE I.—Ratio of the Arithmetic Mean to the Median Density for Various Values of the Geometric Standard Deviation

σ_g	$\frac{m}{C\, m_g}$	σ_g	$\frac{m}{C\, m_g}$
1	1.00	11	17.7
2	1.27	12	21.9
3	1.83	13	26.8
4	2.61	14	32.5
5	3.65	15	39.1
6	4.98	16	46.7
7	6.65	17	55.3
8	8.67	18	65.1
9	11.2	19	76.2
10	14.2	20	88.8

Table I, computed from Eq. 4, indicates the relative sizes of the arithmetic mean and the median (or geometric mean). It may be used to speed calculations involving Eq. 4.

The data (5, Figure 9) plotted in Figure 1 indicate M.P.N.'s observed at the primary sewage treatment plant at Traverse City, Mich. Chlorine was dosed in the influent and effluent of the settling tank. Samples were taken of the effluent of the settling tank and the contact tank. From the probability plot and using Eqs. 4 and 5 with $n = 3$, the following results are calculated:

Effluent	Geometric Mean (colif./100 ml.)	Geometric Standard Deviation	Arithmetic Mean (colif./100 ml.)
Settling tank	1,200	7.5	7,000
Contact tank	11	6	42

It is evident from these values that entirely different conclusions will be reached as to the average density of the effluents and as to the additional kill in the contact tank, depending on whether the arithmetic mean or the geometric mean is used. In another series of tests (5, Figure 8), the geometric mean was 640 coliforms per 100 ml.; using Eq. 4, it may be shown that the arithmetic mean was 39,000.

Coliform frequency distributions are

often markedly skewed, with extremely high densities appearing from time to time. The arithmetic mean, unlike the geometric mean and the median, reflects these high densities, which are important from the viewpoint of possible health hazards. An insight into the inadequacy of the geometric mean and the median coliform densities may be had from consideration of the following hypothetical example.

Example 1:—Tap samples from a distribution system are tested daily for seven days. The coliform density for six days is found to be 1.0 coliform per 100 ml. On the seventh day, owing to backsiphonage from a cross-connection, the density rises to 7,000 coliforms per 100 ml.

The median value (central item when the M.P.N.'s are arrayed in order of magnitude) of the seven test results is 1.0; it would remain 1.0 irrespective of what happened on the seventh day. The geometric mean is $(1^6 \times 7{,}000)^{1/7} = 3.54$; it also does not reflect adequately the extent of the backsiphonage. The arithmetic mean, $(1 + 1 + \cdots + 7{,}000)/7 = 1{,}001$, is markedly influenced by the cross-connection and, therefore, is a better indicator of the average safety of the supply. It alone is proportional to the total number of coliforms ingested during the period.

A more rigorous explanation of the unique relation between the arithmetic mean coliform density and hazard from enteric pathogens may be obtained from a simple probability model.

Consider a water supply in which the typhosa:coliform ratio is constant (1) and in which the coliform density fluctuates from day to day in a more or less random manner but following seasonal trends. During any one day the probability that a person will contract typhoid is proportional to the coliform density obtaining during that day and to the amount of water ingested.

Let p_i be the probability of contracting typhoid on the ith day when the coliform density is u_i. Then from probability theory the following statements hold:

$1 - p_1$ = the probability of surviving (that is, not contracting) the first day.

$(1 - p_1)(1 - p_2)$ = the probability of surviving the second day.

$(1 - p_1)(1 - p_2) \ldots (1 - p_t)$ = the probability of surviving t days.

Therefore, the probability of contracting typhoid during t days,

$$P = 1 - (1 - p_1)(1 - p_2) \ldots (1 - p_t) \ldots (6)$$

With modern sanitation standards the probability of contracting a gastrointestinal disease from drinking water is extremely remote, and the p_i are very small numbers.* In this case, Eq. 6 may be written in the form

$$P = 1 - (1 - p_1 - p_2 - \ldots - p_t) = p_1 + p_2 + \ldots + p_t \ldots (7a)$$

or

$$P = \bar{p}t \ldots (7b)$$

where $\bar{p} = (1/t)(p_1 + p_2 + \ldots + p_t)$, the arithmetic mean probability during the time period. Since the p_i are proportional to the u_i (coliform density), it follows that the hazard of typhoid is

* According to Eq. 1, with a typhoid morbidity rate of 1 case per 10^5 persons per year, there would be one typhoid bacterium for every 3.3×10^5 coliforms. With a 1 per cent infectivity rate, there would be 1 "case-producing" typhoid organism in 3.3×10^7 coliform. The probability, p, of a person ingesting one of these pathogens (and thereby contracting typhoid) in drinking 1 l. of water complying with the USPHS standard of 1 coliform per 100 ml. would be $(1/3.3 \times 10^7)(1{,}000/100) = 3 \times 10^{-7}$.

As far as an individual is concerned, this is a negligibly small hazard; in drinking such water at the rate of 1 l. a day he could expect to survive $1 \div (365 \times 3 \times 10^{-7}) = 9{,}100$ years before contracting typhoid.

From the viewpoint of society, however, the situation has a different aspect. In a nation of 200,000,000 persons, the use of such water would result in $3 \times 10^8 \times 365 \times 3 \times 10^{-7} = 22{,}000$ typhoid cases per year. When hazards from other waterborne enteric diseases are also taken into account, it is manifest that current coliform standards do not provide absolute protection. The aim of the sanitary engineer must be the continued development of waste disinfection and treatment methods that will make economically feasible the adoption of ever-more stringent coliform standards.

proportional to the arithmetic mean coliform density during the period.

The foregoing theory is perhaps oversimplified in that it does not take into account the possibility that larger pathogen:coliform ratios may occur during periods of high coliform density. In this event, an average, such as the quadratic mean that is even more sensitive to large densities than the arithmetic mean, would yield a valid measure of health hazard. At least it may be said in this event that the arithmetic mean would continue to be a much more satisfactory parameter than the median or geometric mean as an index of the degree of safety.

In view of the uncertainties involved and the paucity of reliable data pertaining to the occurrence of pathogens in waters of differing coliform density, it is not possible to place complete reliance on any single average. Additional information relating to the dispersion of coliform densities about the average is needed in order to design and operate treatment plants in a satisfactory manner. Such information is best provided by the geometric standard deviation, σ_g, as obtained from log-probability graphs.

Two raw waters having the same average density might be treated in two plants having the same general design. However, if the density fluctuations as measured by σ_g in one of the plants were considerably larger than in the other, that plant might require additional treatment units for intermittent, or standby, use in order to yield a satisfactory effluent. Certainly the occurrence of wide fluctuations in bacterial density places a premium on vigilant operation.

Design of Coliform Standards

A discussion of the principles of design of rational coliform standards may be facilitated by reference to a particular recent code tentatively adopted by the Ohio River Valley Water Sanitation Commission (6), as based on a competent analysis of extensive coliform data from the Ohio River and its tributaries. The requirements apply to coliform density in the waters of the Ohio at the intake of water plants having pre- and/or post-chlorination and rapid sand filtration. The essential features relating to coliform density are as follows:

During any one month:

(a) The arithmetic mean density, m, should not exceed 5,000 per 100 ml.

(b) The 80 per cent quantile, X_{80}, should not exceed 5,000 per 100 ml.*

(c) The 95 per cent quantile, X_{95}, should not exceed 20,000 per 100 ml.*

In a log-normal distribution any quantile, X_F, may be calculated from the median and the geometric standard deviation according to

$$X_F = m_g \sigma_g^{t_F} \quad \ldots\ldots\ldots (8)$$

where t_F is the standardized normal variate as obtained from tables of the normal probability integral. For the 80 per cent quantile, t_F is 0.842; for the 95 per cent quantile, 1.65.

In view of the foregoing discussion, it is clear that the regnant requirement is the one (a) limiting the arithmetic mean density. For supplies meeting this requirement (m = 5,000), various permissible values of the two quantiles that are compatible with the mean may be specified, depending upon the geometric standard deviation of the supply, which in turn depends on climatological and hydrological factors prevalent in the drainage system. Such calculations are facilitated by an equation obtained by eliminating σ_g between Eqs. 4 and 8 and using the appropriate

* Paraphrased requirements (b) and (c) might read: "M.P.N.'s of no more than 20 per cent of samples in any month may exceed 5,000 per 100 ml., nor may more than 5 per cent of such samples exceed 20,000 per 100 ml."

values of t_p.

$$\log X_{95} = \log X_{80} + 0.293 + 0.747 \left[\log (m/C) - \log X_{80} + 0.154\right]^{\frac{1}{2}} \ldots (9)$$

In Eq. 9, setting m = 5,000 colif. per 100 ml. and C = 0.851, corresponding to 5 tubes in each dilution, the following pairs of values of the 80 per cent and 95 per cent quantiles are found to be compatible with the requirement of an arithmetic mean density of 5,000:

X_{80}	X_{95}	σ_g
100	2,100	44
1,000	10,200	18
3,160	18,600	9.1
5,000	21,900	6.3
7,000	22,300	4.2
8,300	16,200	2.3

The computation indicates an appreciable variation in the permissible quantiles compatible with a fixed mean density. The Ohio River standards are predicated on geometric standard deviation of about 6, which is a reasonable value for a large regulated stream with many sources of pollution.

For smaller or unregulated streams, particularly those having relatively few major sources of pollution, the Ohio River standards would not be satisfactory. In such streams wider fluctuations in density may be expected to occur (large σ_g), and in order to maintain an arithmetic mean coliform density of 5,000 colif. per 100 ml., considerably lower values of the 80 per cent and 95 per cent quantiles may be indicated. In other water supplies, particularly those with intakes in long-detention reservoirs and lakes, fairly uniform coliform densities may occur. For such sources the Ohio River quantile standards might be unnecessarily stringent.

Some coliform codes contain a stipulation limiting the permissible density of any sample to a fixed maximum value. From the viewpoint of the probability theory of bacterial density fluctuations, this is a practice of dubious merit. The objectionable feature of a standard fixing the maximum permissible density is that compliance will depend not only upon the actual numbers of coliforms present, but also upon the frequency of sampling. Unlike such statistical parameters as the arithmetic mean, the maximum item in a random sample tends to increase as the size of the sample is increased. For example, in a supply just complying with the Ohio River standards (m = 5,000 and σ_g = 6), the expected value of the largest M.P.N. is 19,000 when 10 samples are tested during the reporting period. However, if 100 samples are tested during the same period, the expected maximum M.P.N. will be 106,000. Conversely, it follows that two supplies, both of which just meet a standard maximum permissible density, may have vastly different arithmetic mean densities, and therefore correspondingly different capacities for the transmission of waterborne disease.

In general, the most satisfactory coliform code is one specifying primarily the limiting arithmetic mean density. Quantile densities intended to control "over-run" frequencies if specified should be carefully set to accord with the actual fluctuations in density in each source. Since these fluctuations vary greatly in magnitude and frequency in different streams, and in the same stream from season to season, no universally valid limits exist for quantiles that are compatible with a given fixed arithmetic mean density, which by itself is indicative of the safety of the supply. It is important that codes be so worded as to require the collection and analysis of coliform data in such a form that both the average density and the dispersion may be obtained.

Compliance with a code specifying the arithmetic mean density would be judged by plotting the observed M.P.N.'s on log-probability paper and calculating the arithmetic mean density from Eq. 4. The computation is illustrated by the following example:

Example 2: From a log-probability plot of M.P.N. values of samples collected three times a week during the summer months from a bathing beach, the median density is found to be 210 coliforms per 100 ml. and the geometric standard deviation is 6.5. The M.P.N.'s were based upon tests with 3 tubes in each dilution.

Ascertain whether these results indicate compliance with a requirement that the mean density not exceed 1,000.

According to Eq. 4 or Table I:

$$m = (0.764)(210)(6.5)^{1.15 \log 6.5}$$
$$= 921 \text{ coliforms per 100 ml.}$$

Therefore, compliance with the standard is indicated.

Confidence Limits for the Arithmetic Mean Density

In the administration of stream standards by regulatory agencies, judgment on questions of compliance with coliform codes, or on classification of streams is aided by a consideration of the reliability of the observed coliform results. The precision of the arithmetic mean density as computed from tests over an interval of time from a fixed sampling station depends primarily upon two factors: (a) the number of samples tested, N; and (b) the magnitude and frequency of fluctuations in coliform density. Precision is enhanced as the number of tests is increased; it is affected adversely if large temporal variations occur in the numbers of coliform bacteria.

It is true that the precision attained depends in part upon the skill used in fitting lines to data plotted on probability paper. However, it has been found that with reasonable care graphical errors are relatively unimportant. In ascertaining the sensitivity and reproducibility of the graphical method described in this paper, several probability plots were prepared with normal random sampling numbers simulating actual test series of various sizes and types. These were analyzed independently by 18 persons who drew straight lines fitting the points and then computed arithmetic means using Eq. 4. The means were also calculated from the original data by the method of moments according to the usual statistical procedures. The two sets of means were found to have nearly the same amount of dispersion (sampling error) about the true mean, and indicated that the graphical method was almost as precise as the analytical method of moments.

An estimate of the reliability of an arithmetic mean density computed from a log-probability plot of coliform data may be obtained from Figure 2, which gives 50 per cent confidence limits for the true (population) mean density depending upon the observed mean and geometric standard deviation, and the number of fermentation tube tests, including those with indeterminate results. Figure 2 has been prepared using standard statistical procedures for the estimation of population parameters from sample parameters as calculated by the method of moments.

Example 3:—Calculate 50 per cent confidence limits for the true arithmetic mean density for the bathing water of Example 2. The computed mean from 39 samples taken during the bathing season was 921 per 100 ml.

From Figure 2, the ratio of the upper confidence limit to the observed mean for $N = 39$ and $\sigma_g = 6.5$ is read as 1.40. Thus the upper confidence limit is $921 \times 1.40 = 1{,}290$ per 100 ml. The lower confidence limit is $921 \div 1.40 = 657$ per 100 ml. The statement that the true mean density lies between 657 and 1,290 has a 50 per cent likelihood; that is, 50 per cent of statements of this type will be correct.

Calculations such as in this example indicate that sampling errors in coliform tests are apt to be large. Therefore, administrative action should be withheld until sufficient data are accumulated to insure that control measures have an equitable basis uninfluenced by possible eccentricities of the coliform density measurements.

Confidence limits calculated from

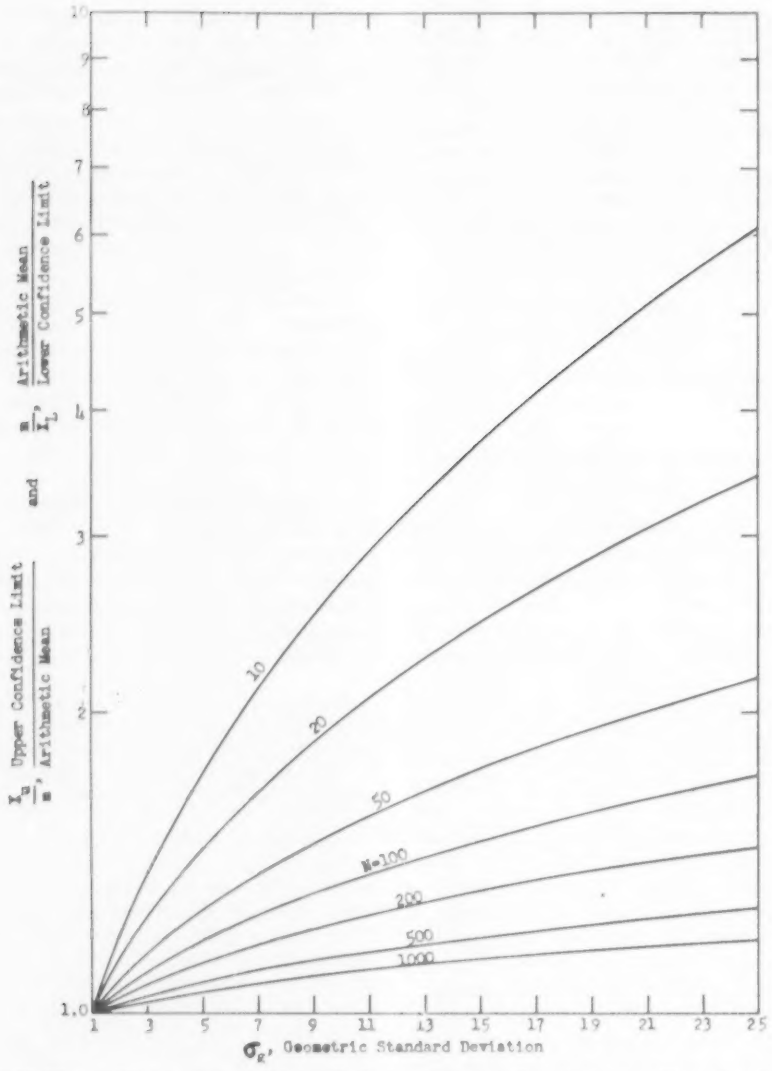


FIGURE 2.—Fifty per cent confidence limits for the true arithmetic mean coliform density.

past observations are useful in assessing the significance of trends in coliform density and in planning future monitoring programs and stream surveys.

Conclusions

1. The arithmetic mean coliform density of polluted waters as calculated from a series of M.P.N. values from multi-dilution fermentation tube tests is a more valid measure of the hazard from enteric pathogens than other averages such as the geometric mean and the median.

2. In order properly to take into account indeterminant fermentation tube test results and to allow for the bias of the M.P.N. as an estimator of

the coliform density, the observed M.P.N.'s should be plotted on log-probability paper and the arithmetic mean density calculated from an analysis of the plot (Eq. 4). A useful additional parameter, the geometric standard deviation, may also be obtained from the log-probability plot; it reflects the magnitude of density fluctuations, thereby providing information of value in the design and operation of treatment plants.

3. The principles discussed indicate that regulatory coliform codes may be improved and simplified by placing primary emphasis on stipulations limiting the arithmetic mean density.

References

1. Kehr, R. W., and Butterfield, C. T., "Notes on the Relation Between Coliforms and Enteric Pathogens." *Pub. Health Rep.*, **58**, 589 (1943).
2. Thomas, H. A., Jr., "On Averaging the Results of Fermentation Tube Tests." *Jour. Boston Soc. Civil Eng.*, **39**, 253 (1952).
3. Nat. Research Council, Div. of Medical Sciences, Comm. on Sanitary Engineering and Environment, Subcommittee on Water Supply. Minutes of the 16th Meeting, Appendix C (Jan. 10, 1952).
4. Hald, A., "Statistical Theory With Engineering Application," p. 160. John Wiley & Sons, Inc., New York, N. Y. (1952).
5. Pierce, D. M., "Two-Stage Chlorination." THIS JOURNAL, **24**, 8, 950 (Aug., 1952).
6. "Bacterial Quality Objectives for the Ohio River." Ohio River Valley Water San. Comm., Cincinnati, Ohio (June, 1951).
7. Eisenhart, C., and Wilson, P. W., "Statistical Methods and Control in Bacteriology." *Bact. Rev.*, **7**, 57 (1943).

APPENDIX—DERIVATION OF FORMULATION FOR THE ARITHMETIC MEAN DENSITY

The initial (*a priori*) frequency distribution of the true temporal coliform density, u, is assumed to have a log-normal form,*

$$f(u) = \left[\frac{1}{\sqrt{2\pi}\ (\log \sigma_{gu})u}\right] e^{Y} \quad . . (10a)$$

in which

$$Y = -\frac{\log^2 (u/m_g)}{2 \log^2 \sigma_{gu}} \quad . . . . (10b)$$

and m_g and σ_{gu} denote the geometric mean and the geometric standard deviation, respectively.

With the fermentation tube test it is not possible to measure the true density directly; instead, an estimate of this variate is given by the M.P.N. (X-value) of the test results. The estimated value generally differs from the true value because of the imprecision of the fermentation tube test and of the bias of the maximum likelihood estimator.

* Napierian logarithms are used in the theoretical development.

Various workers (7) have shown that the M.P.N.'s of replicate tests made on water having a fixed bacterial density, u, are distributed about the mean density approximately in accordance with a log-normal frequency curve.

$$f(X|u) = \left[\frac{1}{\sqrt{2\pi(1.27^2/n)X}}\right] e^{V} \quad . . (11a)$$

and in which

$$V = -\frac{n \log^2 (X/u)}{2(1.27)^2} \quad . . . (11b)$$

and n is the number of replicate tubes in each dilution of the fermentation tube test.

In a series of tests on samples collected periodically at a given station, the observed distribution of M.P.N. values as a result of sampling fluctuations will exhibit a greater dispersion than that of the true frequency curve (Eq. 10). The equation applicable to the observed distribution may be obtained by integrating out the variable

u in the joint frequency function of u and X,

$$f(X) = \int_0^\infty f(X/u)\, f(u)\, du$$

$$= \left[\frac{1}{\sqrt{2\pi}\ (\log \sigma_g) X}\right] e^Z \quad \ldots \quad (2c)$$

where Z is given by Eq. 2*b*, and

$\sigma_g = e^U$ and $U = (\log^2 \sigma_{gu} + 1.27^2/n)^{\frac{1}{2}}$,

the geometric standard deviation of the observed distribution. It may be noted from Eq. 2*c* that the observed distribution, like the true distribution (Eq. 10), has a log-normal form, and, moreover, both distributions have the same geometric mean. However, the observed distribution has a larger geometric standard deviation ($\sigma_g > \sigma_{gu}$).

Finally, the arithmetic mean of the true distribution may be obtained from the first moment of the frequency curve of Eq. 10, expressing the parameter σ_{gu} in terms of σ_g and n.

$$m = \int_0^\infty u f(u)\, du = e^T$$

in which $T = \log m_g + (1/2) \log^2 \sigma_{gu}$ Further,

$$T = \log m_g + 1/2(\log^2 \sigma_g - 1.27^2/n)$$

$$m = e^R\, m_g\, \sigma_g^{0.5 \log \sigma_g}$$

(in which $R = -0.5(1.27^2/n)$)

$$= c\, m_g\, \sigma_g^{1.15 \log_{10} \sigma_g} \qquad (12)$$

where, as in Eq. 4, the factor

$$C = e^{-0.805/n}$$

corrects for the bias and dispersion of the M.P.N. values.

WIDE STUDY AND EXTENSIVE EFFORTS MARK INDUSTRY'S AIR POLLUTION CONTROL CAMPAIGN

Citing the many millions of dollars spent by his own company, by the petroleum industry, by U. S. Steel and others, William R. Chalker, of the Engineering Service Division, E. I. du Pont de Nemours & Co., recently stated that "industry has taken long strides forward in curtailing its air pollution."

Addressing a convention of the American Society of Civil Engineers, he said:

"As of 1953, the expenditures of the petroleum industry had reached $14,000,000 for air pollution control facilities in the Los Angeles area alone. The United States Steel Company announced some time back that pollution abatement facilities for its new Fairless Works would cost $8,000,000. The du Pont Company has spent or authorized some $14,000,000 on air pollution reduction facilities alone, not to mention an additional $21,000,000 on liquid waste control. These are impressive figures. It would be intriguing to know what the present outlay for air pollution abatement facilities is in our country. It must be enormous.

"In addition to its own research, industry is supporting investigations made by private research organizations and by universities. Through trade organizations such as the Manufacturing Chemists' Association and the American Petroleum Institute, industry has been pooling the results of its experience and knowledge of air pollution and its abatement.

"It should be recognized that some of these abatement problems are difficult and that their solution will be slow. Industry, however, is of the opinion that it can solve its air pollution problems in the same orderly manner that has led it to crack many of its other difficult technical problems.

"Industry, aware of its share of air pollution, is spending large sums of money on facilities to catch its dusts and control its gaseous wastes. In the earlier days of air pollution, problems were solved as they were recognized, which was frequently not until complaints were received from the neighbors. Today, the rule is for a more positive approach to air pollution abatement. The du Pont management has recognized the problem and has provided a place for its consideration in all stages from site selection to final plant operation."

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

OPERATOR STATUS

Of current interest to all who are concerned with sewage treatment plant operation and the status of the operator is the resolution adopted at the Operators' Forum in Cincinnati, October 14, 1954. Half of the forum was devoted to salary schedules and job classification. From this discussion came the following resolution:

> That the Executive Secretary of the Federation be authorized by the Board of Control to send a letter to all Member Associations recommending and urging them to start an educational campaign in their areas to acquaint the public and public officials with the importance of securing and retaining competent personnel in waste treatment plants.

The emphasis of this resolution is on an educational program directed at the public and public officials by the Member Associations. By bringing attention to bear on the importance of having competent personnel at our sewage treatment plants, salaries will be benefited and the professional standing of the operator raised to its rightful status.

The Board of Control approved the resolution in principle. This action is in keeping with earlier Board philosophy on salaries which resulted in the salary survey by Boyce and Wisely (see THIS JOURNAL, **25**, 1, 110; Jan., 1953). It is further proposed that the headquarters office of the Federation encourage the use of its facilities as a clearing house for programs on operator recognition.

Salary surveys have been made by several of the Member Associations (THIS JOURNAL, **23**, 7, 919; July 1951; and **25**, 8, 978; Aug., 1953), but their benefit has not been evidenced. Efforts need to be made to bring the salary status and the value of competent personnel to the attention of those who are in a position to take appropriate action—the city officials.

Member Associations can perform a real service to the entire membership by establishing a committee that will promote, through state and local publications (municipal officials' magazines, newspapers, and other public media) a program to bring attention to the public investment in sewers and sewage treatment facilities, particular attention being called to the service that these facilities render the public welfare, the skill necessary in their operation, and information about the operating personnel. The importance of the job should be stressed; service is the key word.

The operator's part in the program is very important. It is necessary that all supervisory personnel start now, if they have not already done so, to acquaint all employees with the importance of their job and the plant to the community. Service to the community must be emphasized and each plant must be operated as efficiently as possible. It must be realized that the only real way for operating personnel to improve their status is to prove their worth.

The program of local publicity, as envisioned at the Operator's Forum, would benefit the community and everyone interested in adequate sewage treatment administered by competent personnel. With full cooperation, the desired results will be achieved.

BASIC ELEMENTS OF DIGESTER OPERATION

By William R. Copeland

Consulting Chemist, Framingham, Mass.

Editor's Note—Mr. Copeland's compact analysis of digester operation is based on the articles appearing in the April 1954 issue of This Journal, and material obtained directly from the authors, plant operators, and engineers in several states. It emphasizes some of the highlights of recent developments in sludge digestion practice.

Control of scum and digestion of sludge in covered tanks involve many complex problems. Among the factors, the following three are of especial importance:

1. The biological, chemical, and physical agencies, upon which the processes depend, must be distributed at all times throughout the digesting materials.
2. The digesting sludge must be kept in constant agitation.
3. To treat the maximum volume of sludge the layer of scum must be reduced to a thickness of not more than 2 ft., and the tank must be kept free from deposits of grit and layers of cold dense undigested matter.

Experiments have shown that, under such favorable conditions, sludge can be digested in a single tank in 10 to 15 days, instead of requiring three or four tanks and periods of 4 to 6 weeks, as has been common practice.

Scum Control

At Washington, D. C., the scum is controlled by forcing digester gas into the sludge. The gas is injected about 10 ft. below the liquid level, at a rate of 300 cu. ft. per minute, through open pipes. The large gas bubbles disintegrate the scum, allowing moisture to penetrate and saturate the material.

At the Bowery Bay facilities in New York City, part of the digester contents is mixed with the raw sludge and pumped into the digester below the scum layer. This, combined with the action of internal stirring devices, disintegrates the scum, and the entire mass of digesting material is agitated.

At Columbus, Ohio, and at Oklahoma City, Okla., the scum is controlled by forcing digester gas into the liquid through diffusers located near the bottoms of the tanks. The plant operators lay particular emphasis on the necessity for determining, by preliminary full-scale tests, the rate of gas application needed to maintain diffusion throughout the tank.

At other plants this system has not been so successful, due apparently to need for additional compressor capacity.

Scum Control by Mechanical Stirrers

Mechanical stirrers of several types have been installed in many plants. It has been reported from New York State, where there are a dozen or more plants equipped with mechanical stirrers, that in no instance has scum formation been a problem.

At Syracuse, N. Y., screenings, skimmings from the primary settling basins, paper towels, etc., formerly were dumped into the sludge digestion tanks. Scum layers 5 ft. thick formed, causing considerable trouble and expense for removal. After installing an incinerator and burning these materials, the scum problem disappeared. The incinerator has provided for simpler operation plus a saving of digester capacity valued at many thousands of dollars.

There are installations of mechanical stirrers at about six plants in Connecticut, and all but one are working effectively. Rules and regulations adopted by the Connecticut State

Board of Health require that the raw sewage entering plants shall pass through grit chambers and screens. At one city, where the raw sewage contains much fur, several feet of scum collected annually in the digesters. The problem was corrected when fine screens were installed to remove the fur.

Engineers and plant operators in Kansas, Illinois, Michigan, Ohio, and Pennsylvania indicate that, where sewage is of a strictly domestic nature, mechanical stirrers are efficient in breaking up scum. But where the raw sewage contains much grease and material that requires several weeks to digest, mechanical stirrers often are not efficient.

Accelerated and High-Rate Sludge Digestion in Covered Tanks

Many of the most important factors in accelerated and high-rate sludge digestion have been described by Fuhrman (4), Torpey (1), Blodgett (5) and others in the April 1954 issue of THIS JOURNAL. Table I was prepared from data presented by Torpey (1) and from material furnished by Blodgett (2).

TABLE I.—High-Rate Sludge Digestion

Determination	Plant	
	Bowery Bay, N. Y.[1]	Columbus, Ohio[2]
Thickened sludge to digester:		
Volatile acids (p.p.m.)	1,820	—
Alkalinity (p.p.m.)	1,110	1,800
Solids, dry (%)	6.0	6.5
Volatile matter (%)	71.9	59.7
pH	5.7	6.5
Pumped (cu. ft.)	12,100	7,400
Digester Liquor:		
Volatile acids (p.p.m.)	360	300
Alkalinity (p.p.m.)	4,400	2,500
Digested sludge:		
Solids, dry (%)	3.4	4.6
Volatile matter (%)	57.9	50.2
pH	7.1	7.2
Temperature (°F.)	93	90

[1] Reference (1).
[2] Reference (2).

Torpey (1) states that it is imperative to reduce the volume of sludge to a minimum as it enters the digester, and advises that small doses should be added every hour or two, rather than large doses once or twice a day. He suggests, however, that the sludge in the digester should be diluted.

The objectives are to secure a maximum amount of space for sludge digestion, and to get rid of the supernatant liquor that otherwise must be drawn from the digested sludge.

Dry Solids

Comparing the values for dry solids given in Table I for the raw and digested sludges indicates that the raw sludge entering the tank should contain not more than 94 per cent water, and the digesting solids in the tank should contain at least 96 per cent water.

Volatile Acids

Volatile acids serve as a check on the process of sludge digestion. A study of Table I reveals that when sludge digestion is progressing favorably the volatile acids will run about 300 p.p.m., but when sludge digestion is not progressing favorably the volatile acids start to build up.

Some sewage plant operators have found that it is desirable to add hydrated lime to neutralize these volatile acids. In doing so it is essential to have the lime mixed thoroughly with all parts of the digesting material. Other operators have not found that it is desirable to add lime. An answer may be that the composition of the raw sludge is the controlling factor. However, experimentation is presumably a good policy.

Alkalinity

The alkalinity of the digesting sludge, is another helpful guide to digester operation.

Experience at Bowery Bay, Columbus, and many other sewage treatment plants has shown that, whereas the

raw sludge generally contains from 1,000 to 2,000 p.p.m. of alkalinity, well-digested sludge contains from 2,500 to 4,000 p.p.m. Consequently, if the alkalinity starts to fall below 2,500 p.p.m. it indicates that the normal biological processes of digestion are slowing down and so the feed of raw sludge should be reduced. An interesting discussion of this problem has been presented by Sawyer *et al.* (3).

pH

Table I shows that the pH values for the raw sludges were 5.7 and 6.5, respectively; for the digested sludges, 7.1 and 7.2, respectively. Therefore, if the pH of the digesting sludge falls below 7.0 it may serve as a warning that the digester needs a rest.

Temperature

Temperatures of from 90° to 100° F. have been found to be favorable for high-rate sludge digestion. Rudolfs (6) and others have experimented with temperatures as high as 130° F. They report that these high temperatures favor sludge digestion. But many plant operators, especially those with digesters 80 to 100 ft. in diameter and equipped with hot-water coils on the walls, have had considerable difficulty in maintaining temperatures even up to 85° F.

Therefore, to maintain high temperatures at uniform rates, large diameter digesters should be equipped with facilities for pumping heated sludge into the tank at several points, coupled with mechanical stirring devices and perhaps coils of hot-water pipe suspended from the roof. At Columbus, Ohio, and some other plants, where facilities for maintaining temperatures of 90° F. are available, pumping the digester gas through diffusers into the sludge at several points maintains temperatures above 90° F.

Biological Factors

Sawyer *et al.* (3) state, "It is well recognized that satisfactory digestion of organic matter under anaerobic conditions depends upon having two totally different groups of bacteria living harmoniously in the same environment." Some groups produce carbonic and organic acids; others, sensitive to pH changes, produce methane.

Values given in Table I indicate that a pH of 7.1 is favorable. Where the composition and physical conditions of the digesting sludge are favorable, the biological agents produce many thousand cubic feet of gas per day; but when the biological and physical factors are not favorable the volume of gas produced falls off. In some cases the volume has dropped from 40,000 to less than 10,000 cu. ft. per day. After the biological balance has once been upset it takes weeks before the balance becomes re-established.

Plant operators have found that after sludge digestion has stopped it is necessary to cut down the feed of the raw sludge to small doses added at intervals of several days. This checks the growth of the organisms that produce acid and permits the slow-growing methane-producing bacteria to become re-established.

References

1. Torpey, W. N., "High-Rate Digestion of Concentrated Primary and Activated Sludge." THIS JOURNAL, **26**, 4, 479 (Apr., 1954).
2. Blodgett, J. H., Private communication (May 24, 1954).
3. Sawyer, C. N., Howard, F. S., and Pershe, E. R., "Scientific Basis for Liming of Digesters." THIS JOURNAL, **26**, 8, 935 (Aug., 1954).
4. Fuhrman, R. E., "Scum Control in Sludge Digestion." THIS JOURNAL, **26**, 4, 453 (Apr., 1954).
5. Morgan, P. F., "Studies of Accelerated Digestion of Sewage Sludge." THIS JOURNAL, **26**, 4, 462 (Apr., 1954).
6. Rudolfs, W., and Miles, H. J., "High and Low Temperature Experiments. I. Operation and Seeding." *Sewage Works Jour.*, **7**, 3, 422 (May, 1935).

FLORIDA OPERATORS' ASSOCIATION HONORS TV STAR

Art Carney, well-known TV comedian and singer of the "Song of the Sewers" on the Jackie Gleason television show, recently was presented with an Honorary Life Membership in the Florida Water and Sewage Works Operators' Association. Endeavoring to capture some of the seriousness of the work of operating personnel, attention was called to the contributions that are made by the operating profession to protect the nation's health. The presentation was as follows:

Mr. Art Carney
c/o "Jackie Gleason Show"
C.B.S. Television Network
R.C.A. Building
New York, N. Y.

Dear Mr. Carney:

For months many Florida water and sewage treatment plant operators have enjoyed your Saturday night performances on the "Jackie Gleason Show." They have always laughed with you when you referred to your "other job in the sewers."

During the 1954 Annual Business Meeting of the Florida Water and Sewage Works Operators Association, held at the University of Florida in Gainesville, it was unanimously passed that you be granted an Honorary Life Membership in our organization. Consequently, you are being mailed under separate cover your Honorary Certificate of Membership along with a copy of the Association Constitution and By-Laws. You might be interested to learn our association has a total membership of nearly 500 members, made up of operators, chemists, engineers, and sales representatives.

Realizing a true comedian also possesses a serious side we know you understand and appreciate the contributions of a profession, such as ours, to society. Among these contributions are the services which help protect the nation's health, comfort, and property by adequately treating the country's wastes and also the production of a safe water for myriads of uses in the home and industry.

We would be honored by your acceptance of this Honorary Life Certificate.

Very truly yours,
Florida Water & Sewage
Works Operators Association

THE DAILY LOG

Aurora, Illinois

By Walter A. Sperry, *Superintendent*

April 16—A call from the office of one of our better housing projects complained of clogged sewers. Investigation revealed that the sewers and house laterals were filled with pulped food, egg shells and coffee grounds. It came out of the house laterals in a solid "sausage." The stuff was piled up in the shallow manholes and was best shoveled into trucks. The trouble was due to insufficient flushing after using the garbage grinders. It proved to be an expensive job of flushing and cleaning for about three days. The folks in this area were economizing too much with their private water supplies. This trouble had never occurred elsewhere in the city. A carefully worded letter of advice and instruction was sent to every home in this area and, so far, we have had no more trouble.

May 7—We were both honored and delighted to have as an all-day guest Mr. C. B. Townend, Chief Engineer of the Mogden (England) plant. We talked shop, visited several up-river plants, and were privileged to have him home for dinner. He commented on and took pictures of our wooden houses and open yards. Supposedly there is little wood in England and all yards are either hedged or fenced—each man in his own stronghold. Commenting on whether we preferred water or sewage work, and learning that we enjoyed sewage work better, he said that in England they quip that the sewage men like their work the better "because there is so much more in it."

May 15—Late this afternoon a tornado ripped a diagonal swath through Aurora, doing much damage. At least 25 large trees on the plant grounds were torn to pieces. A skylight and the roof on the main building group were damaged and the skylight on the screen house was destroyed. The building damage alone totaled $1,396, all covered by insurance. Our good neighbor, the Park Board, loaned us a crew of men to operate two of their power saws to help clear the trees—a two- or three-week job. We later loaned them our road patrol grader. Reciprocal help is the American way and pays good dividends.

May 27—A neighboring farmer with a tomato planting contract was caught with a short water supply. We loaned him our 2-in. portable pump and he used our filter effluent in his planting machine. Subsequent frost forced a second planting, and later a third partial planting. We made no charge. He hauls away our accumulating sludge when time permits. Then one Sunday afternoon he called at the house with a "thank you" present of two fine roasts of beef from his freezer.

June 10—This summer it has been necessary to increase our pumping capacity to the trickling filters to eliminate a portion of our total flow from going to the river with only primary treatment. A float controlled, motor-driven, 6-m.g.d. pump was put in service for the first time. This pump automatically cuts in for a 3-min. run out of about every 10 min. during the daytime flow. Then trouble developed with the 16-in. swing check valve. It slammed so hard that the adjacent lead joints began to leak. A new weighted-type swing check valve would cost about $700 and would be difficult to install. Examination of the valve revealed that the hinge bolt was secured by caps on its ends, placed on the outside of the valve body. A new hinge bolt was obtained some inches longer, so that it

protruded beyond the valve body on one side. The chief operator dreamed up a clever stuffing box made from a nipple, a reducing coupling, and a bushing. The packing in the coupling was secured by the bushing. A 30-in. lever was attached and a 22-lb. sliding weight applied. The device works. It still slams, but not enough to effect the lead joints.

June 15—Another problem is posed by the 6-m.g.d. pump: How much of the flow does it pump? The wet well has a constant inflow and two withdrawals—a steady withdrawal by the gas-engine pump and an intermittent withdrawal by the motor-driven pump. After some timing and some fancy mathematics, we figured that the 6-m.g.d. pump was pumping at a 3,600-g.p.m. rate. It then became necessary to know how many minutes it operated each day and also how many times it cut in per day. A counter was attached to the cable of the float control. After much study and the suggestion of our electrical man, an ordinary motor operating magnetic switch was bought. One side of this was connected into the switch on the float control. The other side of the magnetic switch was wired into the circuit of a Telechron-type electric clock. This type of clock, after current interuption, starts running again when the current is restored. Thus the clock runs exactly as the pump operates. Each morning at "reading time" the clock is reset at 12 o'clock. If the next morning the clock reads 3 o'clock, the pump ran for 180 min. on the preceding day and the counter tells us the number of runs per day.

June 20—Our engine circulating-water system began to act strangely today; the expansion tank began filling up and running over. Finally and reluctantly we decided that the cause could only be from a leak in the copper coils in the water-to-water heat exchanger. After some argument the matter was proved by applying compressed air to the interior of the coils. Air immediately appeared at an air release petcock on the barrel of the exchanger. A new set of coils was ordered immediately. After removal, the old coils looked sound enough. To make sure, a plate and a gasket were applied for a water test. Water squirted from several holes in the interior coils. No visual inspection could have detected them. Our expense was justified; after all, the coils had served for 13½ years.

June 25—Operating a sewage treatment plant constitutes a continuous school of instruction. The babbitt failed in the eccentric ring of the plunger-type sludge pump at the secondary settling tanks. It was then that we learned that this ring could not be babbitted locally and an entirely new connecting rod assembly had to be ordered. The defective one was returned to the factory for repair and to become a spare. Thus a shutdown period on this tank will be avoided sometime in the future.

July 10—Today we acquired a Taylor-type syndet and phosphorus slide comparator. Synthetic detergents are here to stay, and possibly to dog us. During dry-weather flows, daily samples collected at 2 PM are composited for a week and then tested. Syndets, as sodium laurel sulfate, tend to run to 3 p.p.m.; total phosphorus to 9 to 10 p.p.m.; and ortho-phosphorus to 8 to 9 p.p.m. It may be that phosphorus tests might be the more indicative of the amount of syndets present since these compounds are usually fortified with phosphorus salts. Previous tests show that the phosphorus content of the digested sludge is two to three times the phosphorus content of pre-syndet sludges. There is phosphorus in the city water supply.

August 1—Carrol Sanders, day operator and past 65 years of age, resigned today after more than 9 years of faithful conscientious service and attention to his duties. He had slipped and hurt his hip while cleaning an obstruction from a sludge pump. He

was permanently incapacitated and will receive accident insurance compensation. He is our first pensioner; twice before this, the Illinois Retirement Fund has paid death benefits to survivors of plant personnel.

September 7—Finished laying a new power cable today to replace an old cable damaged by lightning, splices, and deterioration. This brings utility power back into the plant to power the 50-hp. motor on our spare 6-m.g.d. pump. The new cable was protected by three sets of lightning arresters, one on either side of the power company's transformers and one on the plant end of the cable. This was recommended as the better practice. We are told that it is definite insurance against lightning damage: the old cable had only one set of lightning arresters, on the outside transformers. The old cable was pulled out of the ground in sections by the plant tractors. The insulation was burned off and the copper and lead sold.

September 15—We learned today that two of our men had scooped some 5 gal. of fishing worms from the effluent channels of the filters, driven over into Indiana, and sold them for $5 per gallon to a fishing bait store. Seems like a lot of effort and gas for $25, but if they can turn an honest penny that way they are welcome. There are, at times, bushels of worms available. Another group of men from a nearby village are also getting worms for planting in earth plots. The worm casts are collected and mixed with soil, and sold by the package for potting plants.

September 24—During 1937, Henry J. N. Hodgson, Chief Sanitary Engineer for the State of South Australia, Australia, spent a day at Aurora. Today we again had the stimulating pleasure of his company.

October 10 and 11—The heaviest rain in 65 years fell on Aurora between 10 PM Saturday and 10 PM Sunday for a total of 10.4 in. In 24 years of plant weather records there have been only five days when the 24-hr. rain was between 3 and 4 in.

The river rose about 6 ft., which is 1.5 ft. higher than any previous record. The flow averaged 11,000 c.f.s., compared with a normal discharge of 990 c.f.s. The water was waist deep on the road at the secondary settling tank. It was over a foot deep in the screen house and clarifier control building. The deeper pump room was saved from flooding by the narrow margin of ½ in. To top it off, the superintendent was in Cincinnati, attending the Federation convention.

Thanks to a loyal, faithful and conscientious crew, the right things were done at the right time. The only plant damage was the shorting of motor circuits in the clarifier control building. Approximately $18,000 damage was done to our Indian Creek interceptor: 90 ft. of 21-in. sewer was destroyed, another 10 ft. was ripped out, and some 230 ft. was undermined. The last section will have to be encased and another 300 ft. uncovered and encased.

Rains such as this one emphasize the fact that once in 100 years the extreme, weatherwise, can be expected.

October 15—Today we had the maintenance man check on the reserve supply of shear pins for the various pieces of equipment. After the flood of a few days ago there is no telling what material may have found its way into the sewers and might unexpectedly turn up in our clarifiers, foul a pump, or get into the comminutor. Shear pins are designed for the protection of the equipment, and there is a particular pin recommended by the manufacturer for each piece of machinery. We don't replace blown house fuses with a penny or anything handy, accordingly the right size and strength pin is used, not a bolt, nail or piece of rod.

CALIFORNIA SAFETY COMMITTEE*

A safety committee has been appointed by the San Francisco Bay Section of the California Sewage and Industrial Wastes Association to make available to the membership information on hazards which may be found, and safety techniques to be practiced at sewage treatment plants. First committee releases are "Manhole and Low-Level Safety" and "Breathing Apparatus Safety."

Manhole and Low-Level Safety

Manholes and low-level structures, found at all sewage treatment plants, present the most common hazard to operating personnel.

Before entering any low-level structure the atmosphere should be tested for both oxygen deficiency and explosiveness. The presence of either condition requires complete ventilation before entering.

In the case of oxygen deficiency only, when ventilation is not possible, a self-contained breathing apparatus must be used. Oxygen deficiency in sewage treatment plant structures can be caused by many different conditions. More deaths are due to the lack of oxygen in low levels than from any other type of hazard. Most of these accidents and deaths are the result of inadequate testing equipment, improper ventilation, and poor judgment.

The following safeguards should be practiced when working in low-level structures:

Safeguards for Work in Low-Level Structures

1. Always test the atmosphere for both explosiveness and oxygen deficiency.

2. Properly ventilate the structure while working.

3. Use a safety harness on the man working in low-level areas. Every safety harness should be kept in good condition. Old or unsafe harness should be destroyed—your own life may depend upon it. At least two men should be at the surface to attend the man below.

4. Always use a self-contained breathing apparatus in a suffocating atmosphere.

5. Do not enter an explosive atmosphere unless it is of an emergency nature; then be sure a self-contained breathing apparatus is used.

6. Don't try to prove you are a "he-man" by working in a suffocating or explosive atmosphere without a breathing apparatus.

7. Don't rush into a suspected area without first making the proper tests.

Certain physical precautions must be used around manholes. Use a pick or a special manhole hook to remove the cover, not your hands. Lay the manhole cover flat and at a safe distance from the manhole. Keep manholes in good repair—no broken or loose rungs, no loose bricks or concrete.

Barricades, flags, or flares should be placed at the proper distance from open structures. Trucks or cars should be placed to afford additional protection.

An atmosphere check takes but a few minutes. Don't rush into an accident or possible death.

Breathing Apparatus Safety

A self-contained type of breathing apparatus is needed at sewage treatment plants. This apparatus does not rely on outside air, nor is it hampered by oxygen deficiency or petroleum fumes. It has a longer service life than the canister-type breathing mask. Since petroleum vapors constitute a hazard when mixed with compressed oxygen, the most versatile mask is a

* Quarterly Newsletter, California Sewage and Industrial Wastes Association, Sept., 1945.

self-contained unit using compressed air and not compressed oxygen.

All personnel should be thoroughly trained in the limitations of their particular apparatus, and periodically checked on the proper use of the mask. The life of an operator may depend upon his co-worker's understanding of the mask.

Masks should be inspected once a week, looking particularly for breaks or cracks in the rubber parts. Each canister must be checked for condition, and the cylinders for proper pressure.

Make certain the harness is in good order and properly installed. Thorough cleaning of the apparatus is necessary after each use. The facepiece should be cleaned with ethyl alcohol and allowed to dry before storing. Locations for the masks should be selected with care so that they will be available at the place of most likely use. However, the location should always be outside the danger area.

An improperly maintained mask is worthless in the hands of a trained person.

SCREW CONVEYOR FOR DIGESTER GRIT REMOVAL

By Andrew Palmer

Superintendent, Plainfield Joint Meeting Sewage Treatment Plant, Plainfield, N. J.

At the Plainfield (N. J.) Joint Meeting sewage treatment plant, two digesters had been in continuous service since 1932 and had never been cleaned.

Tests conducted on the digestion efficiency indicated that the digester volume was appreciably reduced due to the presence of grit. The present grit chamber was not constructed until 1939. This later addition of a grit chamber, plus the fact that some grit passes through even a well-designed and operated grit channel, resulted in approximately 6 ft. of grit being deposited in the digester.

Because the grit was too heavy to be pumped, it was necessary to undertake the task of manually emptying the digesters. After various methods were tried, all too slow, a device was made from a 20-ft. length of 6-in. steel pipe. Into this pipe a 6-in. screw conveyor was placed with a 2-hp. electric motor mounted on the upper end, where a cutout had been made in the pipe. This pipe was dropped through the manhole in the floating cover, after the sludge had been drawn down to grit deposit. A wooden trough was built from the pipe outlet to the side of the digester.

With this arrangement the heavy grit and sludge were conveyed from the bottom of the digester to the trough and thence to the outside of the digester, at the rate of 7.5 cu. yd. per hour. When the grit and sludge were lowered to within 1 ft. of the digester bottom, the end of the pipe was placed in a barrel and the grit shoveled into the barrel where the screw conveyor could take it out.

The equipment worked very well on both digesters. Sludge and grit were disposed of by spreading on fields and plowing under.

In cleaning the second digester the heating coils were found to be badly pitted, gas piping was useless, and the gas dome was in very poor condition. After a careful survey, it was decided to install new heating coils, gas piping, and supports, and to repair the gas dome.

To save the existing gas dome, which was badly pitted and corroded, repair was made by inserting a tight fitting sleeve placed in two sections. The

sleeve, made of ⅜-in. steel, was fitted to the inside of the dome so tightly that it had to be jacked into place.

Since the digester was completely empty and well-ventilated it was possible to weld the sleeve integrally to the existing dome. The net result was to provide a dome thicker than the one originally installed. The dome's interior surface was heavily coated with a bitumastic compound.

All the work on the two digesters was done by the plant personnel. The time required to empty and clean the second digester, install the wrought iron gas and heater piping, plus the repair of the gas dome, took two and one-half months. Work was undertaken only when time and weather permitted.

With thicker steel work, to resist pitting caused by corrosion, and an adequate protective coating bonded to the metal, digester structural sections and metal work will have a long life.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Safety is an intangible something—you can't see it until it ain't."—*Justin Wilson*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Waterbury, Conn., Sewage Treatment Plant for the Year 1953

By Walter M. Kunsch, *Superintendent*

General

Although this is the second annual report, the twelve months covered represent the first full year of substantially uninterrupted operation.

Designed to furnish primary treatment for an average flow of 15.0 m.g.d., the sewage treatment plant was completed in late 1951 at a cost of approximately $1,000,000. The raw sewage is primarily domestic in character, with a minor portion of industrial wastes. However, an analysis of the combined wastes in 1949 disclosed that copper and chromium were present in sufficient quantities that sludge digestion could not be satisfactorily utilized. Vacuum filtration of the raw sludge was decided upon. Decision to construct a refuse incinerator as part of the over-all project made it feasible to construct a flash drying system for the sludge cake, as well as facilities for either bagging or incinerating the resultant dry sludge.

Personnel

Continuous efforts were made to develop an efficient staff of employees who are also satisfied enough with salaries and working conditions to stay more than a few months.

The high turnover in personnel does not make for effective operation. Staff requirements are 32 (for sewage treatment and incineration), with only 16 remaining of those who started the year.

Plant Units

All sewage flows less than 30 m.g.d. are diverted to the treatment plant by means of a control chamber with a central baffle wall located in the main interceptor. Two sluice gates permit complete bypassing of the plant.

A mechanically cleaned 1-in. bar screen, with a grinder, permits the return of screenings to the sewage. Grit from the mechanically cleaned grit chamber is either washed by recirculation or stored in cans for removal. A manually cleaned bar screen is provided for bypass purposes.

Four low-lift horizontal centrifugal pumps (4,200 to 8,400 g.p.m.) raise the sewage from the lower level of the grit chamber and wet well to the settling tanks.

Settleable solids are removed from the sewage in three mechanically cleaned rectangular tanks. Scum is manually discharged to the grease removal pits. Detention time averages 2.5 hr. for a flow of 15 m.g.d. An effluent Parshall flume measures the flow.

The chlorine building, housing two 1-ton chlorinators, provides storage for two carloads of ton containers. Both pre-chlorination and post-chlorination were tried, with the latter producing acceptable results at less cost than pre-chlorination.

Sludge is stored and concentrated in two concrete tanks having a capacity of 50,000 gal. each. Primary sludge is discharged above the tank liquid level and supernatant liquor can be withdrawn from two levels to an adjacent observation tank.

The sludge filter building houses the bulk of the equipment for pumping, conditioning, filtering, conveying and drying sludge. Lime and ferric chloride are used to condition the sludge prior to filtration on two cloth-type vacuum filters. Filtrate and washings from the filters return to the raw sewage wet well. Filter cake can be conveyed to a truck for ultimate dumping or, when heat is available from incineration of refuse, it can be flash dried.

Operation

The average daily sewage flow in 1953 approached the design value and the average suspended solids of the raw sewage ran considerably higher than the 102 p.p.m. originally predicted. However, the pH compared favorably with normal domestic sewage, in spite of expectations of more acid conditions.

Grease content of the raw sludge gave the most difficulties in plant operation, particularly in sludge processing. The grease was partially responsible for the rapid blinding of the cotton cloths on the vacuum filters. During the last three months of the year polyethylene and saran cloth screens were used. The effect of grease on the actual filtration was greatly reduced, resulting in an increase in filter cloth life from 200 hr. to more than 500 hr. Conditioning chemicals were not needed during these three months, and all of the sludge can now be effectively dried in one shift using one or both filters. However, the grease continues to hinder plant operation, accumulating throughout the sludge piping system.

Difficulty was experienced in obtaining sufficient heat from the incinerators to dry sludge, particularly during extended rainy weather or the fall canning season. It will be necessary to install an auxiliary oil-fired furnace to supply heat to the sludge flash-dryer.

During the year the treatment facilities were bypassed on 29 days due to necessary changes in plant structures. As a result of the improvements made in 1952 and 1953, it appeared that most of the operating difficulties had been overcome and that the goal of uninterrupted operation would be reached.

A summary of 1952 and 1953 operating data is given in Table I.

TABLE I.—Summary of 1952 and 1953 Operating Data for the Waterbury, Conn., Sewage Treatment Plant

Item	Average 1953	1952
Connected population (est.)	95,000	95,000
Rainfall, total (in.)	49.44	53.1
Temperature, mean (°F.)	53	52
Full operation (days)	336.25	260.76
Sewage treated:		
M.g.	4,751.07	3,905.82
M.g.d.	14.13	13.76
G.p.c.d. (est.)	147	145
Grit (cu. ft./mg.)	3.20	2.52
Screenings (cu. ft./mg.)	2.12	1.57
Grease (cu. ft./mg.)	2.11	1.51
Dry solids removed (1,000 lb.)	3,669.3	2,343.6
Suspended solids:		
Raw (p.p.m.)	159	130
Final (p.p.m.)	72.1	63
Reduction (%)	54.8	51.5
Volatile (%)	84.1	83.9
Settleable solids:		
Raw (ml./l.)	4.0	3.4
Final (ml./l.)	0.23	0.14
pH:		
Raw	6.9	7.0
Final	6.8	6.8
Chlorine:		
Dose (p.p.m.)	11.1	9.7
Residual (p.p.m.)	0.93	0.61
Sludge processing:		
Gallons per operating day	28,100	25,240
Volatile solids (%)	79.3	78.3
Filter cake:		
Dry solids (lb.)	3,224,740	1,938,750
Dry solids (lb./day)	9,590	—
Operating time (hr.)	4,101	2,590
Filter rate (lb./sq. ft./day)	3.15	2.99
Utilities and chemicals:		
Water (m.g./mo.)	1.52	1.01
Electricity (kw.-hr./mo.)	41,412	32,368
Chlorine (lb./day)	1,075	1,055
Ferric chloride (lb./yr.)[2]	66,932	78,100
Lime as CaO (lb./yr.)	133,746	162,200
Cost data ($):		
Salaries	67,910.25	59,614.02
Insurance	2,592.33	3,169.65
Utilities	14,728.67	12,711.86
Fuel	1,821.77	2,691.01
Supplies	3,467.08	3,563.67
Equipment and maintenance	2,094.80	776.03
Chemicals	16,480.10	19,655.56
Total	109,095.00	102,942.43
Per mg.	22.96	28.70
Per capita	1.15	1.08

[1] Using both filters.
[2] As 100 per cent $FeCl_3$.

1953 Annual Report of the Industrial Wastes Section Waste Treatment Facilities, Atomic Energy Commission, Los Alamos, N. Mex., Field Office

By C. W. Christenson, *Chief*

Treating wastes to reduce the "number of counts per minute," rather than suspended solids or B.O.D., is the objective of the treatment facilities serving the radiological laboratories at the Los Alamos A.E.C. field office. Waste materials contain plutonium having from 100 to 500,000 counts per minute per liter (c.p.m. per liter). The effluent count must not exceed 165 c.p.m. per liter.

Laboratory operation is variable, with the result that the pH of the waste may range from 2 to 13 and the total solids content from 230 to 8,000 p.p.m. Substantial amounts of organic matter are not present.

Plant Hints

The waste treatment plant was designed to provide prolonged flocculation and sedimentation, and filtration through sand at low rates. Lime and caustic soda are used for neutralizing the raw waste. Influent holding tanks, with two days storage volume at normal flow of 70 g.p.m. per 8-hr. day, provide for equalization of the waste or the holding of unusual wastes for gradual blending with waste more amenable to treatment.

Flocculators, chemical feeders, and settling tanks are provided for either parallel or series operation. Ferric salts are used for chemical treatment. Settling tank detention time is 3 to 6 hr. The three rapid sand filters (17 sq. ft. each) are similar to those found in conventional water treatment plants using sand and anthrafilt. Backwashing facilities and a surface wash system are provided. The filtration rate is varied between 1 and 3 g.p.m. per square foot. Most of the residual plutonium activity carried over from the settling tanks is retained with the fine floc on or near the surface of the sand.

Filter effluent is collected in effluent holding tanks, where it is checked to insure a count within the permissible range for plutonium before discharge into a canyon. Backwash water is returned from the filters to the influent holding tanks for re-treatment. The settled chemical sludge from the sedimentation basins is concentrated in a tank. Supernatant from the sludge is returned for re-treatment and the sludge is dewatered on a drum filter 1 ft. wide and 3 ft. in diameter. The filter cake is caught in salvaged oil drums. Final disposal is by burial of the drums in a contaminated burial ground.

Operating Data

Since the plant is essentially experimental, operation is very closely supervised. Because of the high capital cost ($200,000), technical supervision, and low waste volume, the treatment cost is $5.86 per 1,000 gal., which is extremely high compared to municipal or other industrial waste treatment. On the other hand, it is very low compared to costs for radioactive waste treatment where evaporation is required. Costs of chemicals, maintenance, and utilities are about average for a conventional plant.

Results of operation for the year 1953 are summarized in Table II. Note the arrangement of data to show maximum, average, and minimum values. Treatment facilities are operated only during the 8-hr. working day when the laboratories are used.

The average flow to the plant is based on calendar days, whereas the average treated is based on working days. The difference between total to plant and total treated is due to backwash water, operational water, and contributions from the plant laboratories. The difference between total sludge produced and sludge treated

represents the amount of supernatant drawn from the sludge storage tank. Since sludge from another plant is brought to this plant for filtration, only 1,900 cu. ft. can be attributed to the wastes treated at this plant. This represents material that is buried from a total of 6,890,600 gal. of waste.

TABLE II.—Summary of 1953 Operating Data at A.E.C. Laboratory Waste Treatment Facility, Los Alamos, N. Mex.

	ANNUAL
Days operated	262
Hours of plant operation	18424 / 7.0
Treatment rate — gpm	— / 70
Flow to plant 1000 gal	6890.6 / 189
Wash water 1000 gal/wash	340.3 / 1.5
Final effluent recirculated 1000 gal	580 / —
Total treated 1000 gal	77689 / 29.7
Sludge produced 1000 gal	92.80 / 0.37
Sludge treated 1000 gal/run	86.95 / 0.49
Sludge treatment rate — gph	— / 216
Filter cake produced cu ft/run	2839 / 15.9
Filter cake production rate cu ft/hr	— / 0.7
Wet sludge % Solids	— / 9.2
Filter cake % Solids	— / 27.5
Av. filtration vacuum—in of Hg	— / 13
Vacuum filter run — hours	4006 / 23
Sludge filter aid—lb	6300
Wash water %	4.3
Av. filter run—hr	18
Av. rate—gpm/ft²	1.80

	ANNUAL
Influent gross α 1000 cpm/l	— / 4.9
Influent Plutonium 1000 cpm/l	— / 4.3
Influent Plutonium milligrams	1934 / 5.3
Settling basin effluent gross α cpm/l	— / 315
Final effluent gross α — cpm/l	— / 105
Final effluent Plutonium cpm/l	— / 49
Influent pH	— / 7.8
Raw feed pH	— / 7.8
Final eff. pH	— / 9.7
Neutralization lb — NaOH ppm	5002 / 86
Chlorination lb — $Ca(ClO)_2 4H_2O$ ppm	886 / 8.7
Flocculation lb — $Ca(OH)_2$ ppm	12204 / 188
Flocculation lb — $Fe_2(SO_4)_3 \cdot H_2O$ ppm	1540 / 47
Flocculation lb — $Al_2(SO_4)_3 \cdot H_2O$ ppm	1064 / 29
Flocculation lb — Na_2SiO_3 ppm as SiO_2	768 / 3.2

Legend:

Milligrams: 8 — Total; 34.0 — Max; 3.4 — Av; 0.8 — Min

1. Average flow to plant is based on calendar days. Average total treated is based on working days.
2. Average pH values are medians, all other average values are arithmetic means.
3. Parts per million values are based on weights of commercial grade chemicals.

The presence of citric acid and soap gave rise to the main operating problems. The effect was to carry excessive amounts of plutonium through the treatment process. This condition was overcome by raising the pH. However, sludge dewatering was the process bottle neck.

Operating Results

For operational purposes the effluent radiological count is averaged over a two-week period, and the waste discharged only if it does not raise this average above 165 c.p.m. per liter, the drinking-water tolerance for plutonium. A two-week period may be more stringent than needed; however, a conservative approach has been deemed best. It was necessary to recirculate the effluent for re-treatment only five times during the year. The average plutonium content of the effluent discharged was 49 c.p.m. per liter.

The effluent is discharged to a canyon which is usually dry except from storm flows or snow melt. Downstream the effluent is joined by the discharge from a 0.75 m.g.d. domestic sewage treatment plant and by a second 0.75-m.g.d. plant a mile farther below. The combined stream flows 2 to 4 mi. before disappearing completely beneath the coarse sand detritus in the bed of the canyon.

Samples of soil are checked from various points in the canyon bottom for plutonium content. A gradual increase has been detected, but no health hazard is anticipated. Ground-water samples are also obtained. To date no measureable plutonium contamination of the main aquifer (800 to 1,200 ft. deep) has taken place, although minute concentrations having no health significance have been detected in the lens of perched water (120 to 210 ft. deep).

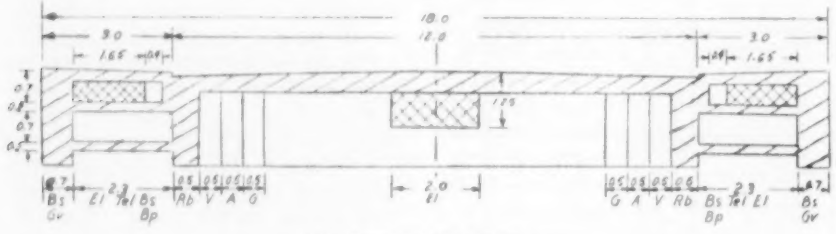
Both the concentration of radioactive material and the quantity of waste received for treatment had increased by the end of 1953.

STOCKHOLM, SWEDEN, PLAN FOR LOCATING SEWERS

Editor's Note—The plan submitted by Mr. Cronstrom is the result of a request in the April 1954 issue of THIS JOURNAL (page 571) for information regarding the relative merits of installing sanitary sewers in the streets rather than on the rear property lines when there are no alleys available.

In Sweden the subject of sewer location is discussed, even as it is in the United States. Mr. Anders Cronstrom, Civil Engineer with the City Street Department, Stockholm, Sweden, advises that considerable study has been devoted to finding the best way to put in sewers without interfering with water mains, storm sewers, gas pipes and electric lines. Most of the utility lines in metropolitan Stockholm are buried in the street right-of-way.

A special report published by the Swedish Community Engineering Committee shows a plan (Figure 1) that has been successfully used in Stockholm. The use of this arrangement facilitates the location of pipes and conduits with a minimum of interference with other lines or private property. The various utilities are arranged in the same general order regardless of street widths. On narrow right-of-ways the utility arrangement is usually concentrated on the side of the street having a sidewalk.



(All dimensions in meters.)

A Sewer
Bp Fire plug
Bs Electric lines
El High tension lines
G Gas line
Gv Gas vent (check point)
Rb Storm water
Tel Telephone lines
V Water mains

FIGURE 1.—Normal plan for utilities, Stockholm, Sweden.

TIPS AND QUIPS

Daily Diary

Few plant operators keep the most important report, the daily diary or log. Operators who keep one find it to be a valuable reference.

For instance—when did you last sharpen and change the comminutor teeth? What did you buy, from whom, at what cost? Who visited the plant? What letters or reports did you write? Who complained about something, and why, and when? What was done about it? What work was performed and why?

These and many other questions can be answered if you keep a daily diary. Such a record is invaluable in preparing your annual report, or in your public relations program. Good plant operation hinges on knowing what was done, when it was done, and why, in order to maintain smooth operation and avoid trouble in the future.

It takes less than five minutes per day to keep a daily diary, yet the reference value is inestimable.

TCP

TCP is a gasoline additive to give power, mileage and pep at no extra cost.

According to the October 1954 issue of *Sewage Gas*, quarterly news-sheet of the Boise, Idaho, sewage treatment plant, TCP stands for:

T—Treatment
C—Cleanliness
P—Public Relations

They cost no more, but the results will out-do any gasoline additive!

End Wrench for Tight Places

Using a wrench on pipes in those hard-to-get-at-places against flat surfaces or in coils should be easier using a new end wrench designed with an offset handle. The wrench is made for rugged duty and hard tough work, according to the manufacturer, the Toledo Pipe Threading Machine Co., Toledo, Ohio. Other features of the wrench, which is available in 8-in., 10-in., 14-in., and 18-in. sizes, are reported to be easier setting of the jaws, improved sure-grip handle, positive hook action, and a handy pipe scale on the hookjaw.

Weather Relations

Does the public look to your plant for local weather information? A number of sewage treatment plants in small and medium size communities furnish weather information to the local newspapers, fuel dealers, and others. Here is a public service feature that will score high in your public relations efforts.

To facilitate the gathering of weather data, the Aircraft Components, Inc., Benton Harbor, Mich., have announced a new weather instrument, the AC-2 Wind-O-Meter for measuring wind velocity (to 85 m.p.h.), wind direction, and air temperature (− 40° to 120° F.) Outside units are connected electrically to an inside desk-top indicator. The cost is reported to be less than $100.

Field Sketch Pad

A ruled sketch pad has been made available by the Automatic Control Company, 995 University Ave., St. Paul 4, Minn., for use in laying out and planning sewer systems or treatment facilities. A number of special symbols are printed on the edges of the sheets to help standardize on simple pictorial representation of processing elements that must constantly be illustrated.

These pads, printed on lightweight stock in orange ink, are available upon request to Automatic Control Company.

Ohio Operator's Exam

Examinations for certification of sewage treatment plant personnel in Ohio will be held on April 22, 1955, in five Ohio cities. Applications must be filed with the Advisory Board of Examiners, Ohio Department of Health, Columbus, Ohio, by March 1, 1955.

Filter Fly Control

It happened much by accident. The operator of the Illinois State Farm at Vandalia, Ill., noticed that filter flies were attracted to and trapped in a pool of No. 1 fuel oil that had resulted from a fuel line leak near the filters. According to the August 1954 issue of *The Digester*, the operator was aroused by this observation and placed several coffee cans around the plant grounds, with a small amount of fuel oil in each. At last report each can had filled with dead filter flies to a depth of ½ to 1 in.

Thus the contest to control filter flies has another entrant!

Safer Winter Driving

Winter driving on snow and ice is always hazardous and requires that the driver "get the feel" of the road *before* going too far and too fast.

A recent news report from the University of Wisconsin, where safer winter driving is studied, states that the use of special tires and chains contributes considerably to safety. Some types of mud-snow treads may serve satisfactorily 80 per cent of the time and reinforced fire chains cut "braking" distances as much as 40 to 50 per cent. However, the responsibility is not diminished for driving within the limits of the "feel" of the road. It takes 3 to 12 times as far to stop on snow and ice as on dry concrete.

For emergency help in getting out of aggravating winter driving situations, the following items are recommended for every well-equipped car or truck—plastic windshield scraper, a shovel, a pail of sand, a tow chain, and reinforced tire chains.

TV and PR

Educational television programs can be an effective medium in any public relations activity. Water conservation, stream pollution abatement, or sewage treatment plant awareness—whatever you wish to call it—can be materially benefited by well-prepared programs.

A graphic picture of the many and varied problems existing throughout the polluted Potomac was effectively brought to public attention through a series of TV shows presented over station WNBW-NBC, Washington, D. C. The response by viewers was most gratifying and efforts are planned to continue this type of public service educational program.

The film used in the program is available to those interested in either showing it or preparing their own program.

Kalamazoo River Responds

Field checks one year after a 1953 fish killing, at almost identical flow rates, showed definite improvement in water quality of the Kalamazoo River below Kalamazoo, Mich.

Recent completion of treatment facilities at 5 more paper mills leaves 6 mills, out of the original 17, yet to be serviced by treatment facilities. By next Fall all paper mills, as well as the municipalities of Kalamazoo, Parchment, Plainwell, and Otsego, are expected to have treatment facilities operating.

Waste Water Reclamation

The day may soon be here when sewage treatment plants will be referred to as water reclamation plants.

Acceptance of sewage treatment plants by the community may be enhanced when the plants are designated and operated for reclamation purposes. This approach would influence city layout, collection system design, and final disposal methods. The economic alternatives between methods of sewage disposal should, then, take into account the value of the waste water resource not only to the city, but also to the entire region. At present, many communities are obliged to think of waste water only as an expensive disposal problem.

Waste water should be a water resource.

Reviews and Abstracts*

Operating Methods of Brush Aeration for Sewage Purification with Activated Sludge. By H. Kessener. *Gesundh.-Ing.*, **75**, 12 (1954).

The activated sludge process is not necessarily as sensitive to shock loadings as the literature maintains. Sufficient oxygen at all times is the problem. The effect of recirculation on high-rate trickling filters can also be obtained for the activated sludge process. Return sludge properly diluted with effluent is defined as external recirculation. Internal recirculation, combined with step aeration, is achieved by pumping mixed liquor from the second tank of two adjacent passes to the first tank by means of water wheels driven by the brush shaft. The amount of recirculation is controlled by several gates or valves along the dividing wall of the tanks. Internal recirculation dilutes shock loads, maintains oxygen levels and sludge absorptive powers. Reserve aeration tanks are unnecessary because the sludge cannot settle and all aeration mechanisms are accessible from the surface. Energy requirements for small plants are relatively little more than for large plants. Peter K. Mueller

Sewage Temperature and Performance of Activated Sludge Plants. By R. Krause. *Gesundh.-Ing.*, **74**, 291 1953).

The expression $k_{20}t_{20}/k_{20}t_T$, in which k_{20} = B.O.D. reaction rate constant at 20° C., and t_{20} and t_T = aeration time in days at 20° and T° C., is a measure of the quantity of carbonaceous B.O.D. applicable at t_T under the following mathematical conditions: (*a*) the influent B.O.D. is 90 per cent destroyed, (*b*) the initial B.O.D. load is unity at 20° C., and (*c*) the aeration tank volume is unity. Thus, at 20° C. the expression is unity and from published operational data corresponding values at 25° and 30° C. are 1.13 and 1.35, respectively. Values at other temperatures for 90 per cent removal, values at other temperatures for 80 per cent removal and for different temperature coefficients of k_{20} are tabulated. Setting similar conditions, but taking B.O.D. loads as unity at each temperature for conventional aeration (I) corresponding values are calculated for step aeration with four steps (II). Thus, unit loading of I at 20° C. corresponds to a loading of 1.79 for II, and unit loading of I at 30° C. corresponds to a loading of 1.69 for II. There is good agreement with literature values. Similar calculations at different temperatures for an infinite number of steps indicate maximum attainable loadings for a given degree of purification. For aeration tank design, annual sewage temperature variations should be considered. Peter K. Mueller

Control and Disposal of Kraft Mill Effluent. By W. A. Moggio. *Proc. Amer. Soc. Civil Eng.*, **80**, Sep. No. 420 (Mar., 1954).

The Kraft paper process, from pulping on through the paper mill, is described with the aid of flow and mass diagrams. Information is also given on sources and characteristics of the wastes and what is currently being done to control them. Spent cooking liquor is processed to reclaim chemicals and where formerly salt cake losses ran up to 500 lb. per ton of pulp some mills now operate with losses below 100 lb. per ton. Re-use of waters, improvements in evaporators, better by-product recovery, and use of improved vacuum washers and save-alls, have combined to reduce losses and give effluents containing 20 to 40 lb. B.O.D. per ton of product.

Treatment and disposal of Kraft mill

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

effluents is by dilution, either controlled or not, or by controlled natural stabilization followed by discharge to receiving waters. An accelerated treatment by the activated sludge process is now being developed. W. A. HASFURTHER

National Water Policy. By T. SAVILLE. *Proc. Amer. Soc. Civil Eng.*, **80**, Sep. No. 442 (May, 1954).

The author does not attempt to establish recommendations for a national water policy, but explores the needs and makes suggestions for a program he considers a major undertaking which will require much time. A national policy is not a federal one and there must be adequate planning representation of federal and non-federal government, and private interests.

The need is stressed for a separate hydrological data collecting agency to take over and supplement work being done by a number of existing agencies. Present data on supply and use are confusing and clear up-to-date reports are needed.

Changing and multiple uses for water dictate the need for better planning, possibly on a river basin scale and with ground waters considered. Non-federal projects are planned and operated on the basis of the users or beneficiaries reimbursing capital costs with interest and this should be a goal. Many other ideas are presented that should stimulate planning necessary to develop an adequate and workable water policy.

W. A. HASFURTHER

Recent Pennsylvania Experiences of Authority Sewage Works Financing. By SAMUEL I. ZACK. *Proc. Amer. Soc. Civil Eng.*, **80**, Sep. 453 (June, 1954).

The methods of awarding contracts and sale of bonds, establishing trust indentures, setting up of sewer connection and rental charges, regulating industrial wastes, and providing for payment of bonds and plant maintenance are covered for eight treatment plants operated by sewer authorities in Pennsylvania.

Fourteen tables and several figures show in fair detail such things as design data, construction costs, bonds issued, interest rates, years of maturity, connection and sewer rental charges, interest and amortization schedules, and actual revenue and expenses. W. A. HASFURTHER

Concentration of Combined Primary and Activated Sludges in Separate Thickening Tanks. By WILBUR N. TORPEY. *Proc. Amer. Soc. Civil Eng.*, **80**, Sep. No. 443 (May, 1954).

Results of 19 months of full-scale studies at the Bowery Bay plant in New York City have shown that the concentrating of combined primary and secondary sludges in separate thickening tanks can result in worthwhile savings in digester capacity. To eliminate laborious calculations, control was governed by a sludge volume ratio (SVR), defined as the volume of the sludge blanket in the thickeners divided by the volume of sludge pumped from them daily. Actual detention time of the sludge varied but was always under one day.

With combined primary and modified activated sludges, concentration of total solids in the thickened sludge averaged 11.2 per cent, and the unit volume to be digested was reduced by 64 per cent over the volume produced by conventional operation. For combined primary and full activated sludge the average total solids of thickened sludge was 6 per cent and the net saving in sludge volume to the digester was 42 per cent.

Special considerations must be given to provision of extra-duty equipment in the thickeners, high sludge pump discharge pressures, and provision of a continuous flow of fresh dilute sludge.

W. A. HASFURTHER

Experiments with Biological Destruction of Phenols with Aeration Using Microorganisms of the Species *Nocardia*. By G. BRINGMANN. *Gesundh.-Ing.*, **75**, 252 (1954).

The fungus *Nocardia rubra* was acclimatized by additions of mineralized 100-p.p.m. phenol solutions to destroy 500 p.p.m. in 24 hr., or 1,600 p.p.m. in 48 hr. when using 1 l. of air per minute per liter of solution. Concentrations above 2,000 p.p.m. retarded growth. Activity can only be maintained by continuous loadings which may vary by ±200 to 300 p.p.m. Variations by ±400 p.p.m. are detrimental. Removal of organisms from the effluent was achieved by sand filtration and inoculation occurred by backwashing with mineralized influent. Temperature changes between 16° and 24° C. had no

effect. Cultures acclimatized to 1,000 p.p.m. phenol destroyed similar concentrations of *o*-, *m*-, and *p*-cresols.

PETER K. MUELLER

Permissible Dose from External Sources of Ionizing Radiation. Nat. Bur. of Stand. Handbook 59, Supt. of Doc., Washington 25, D. C. 79 pp. Price, $0.20 (1954).

The recommendations and discussions of permissible dose contained in this Handbook form the basis of all other recommendations of the National Committee on Radiation Protection, including permissible doses for radioactive material within the body, safe handling of radioactive materials, waste disposal, etc. For easy reference the exposure limits of parts of the body to various types of ionizing radiation are briefly stated in the section "Protection Rules."

This report was used as a basis for the discussion at the meeting of the International Commission on Radiological Protection in Copenhagen in 1953. The general principles developed by the subcommittee have been included in the most recent international recommendations.

H. P. O.

Pollution Sources in Wool Scouring and Finishing Mills and Their Reduction through Process and Process Chemical Changes. BY JOSEPH W. MASSELLI AND M. GILBERT BURFORD. New England Interstate Water Pollution Control Commission, Boston, Mass. 31 pp.

This is a companion study to one previously published (see THIS JOURNAL, **26**, 9, 1109; Sept., 1954) on cotton finishing wastes.

Wool scouring and finishing mills using soap for scouring, fulling and washing will discharge 400 to 500 lb. of B.O.D. for each 1,000 lb. of cloth, about one-half being contributed by the grease and suint in the wool and one-half by the soap, acetic acid, and other process chemicals. Soap contributes 60 to 90 per cent and acetic acid 5 to 30 per cent of the process chemical B.O.D.

Finishing plants not scouring grease wool will produce 150 to 200 lb. of B.O.D. for each 1,000 lb. of wool if soap is used for fulling and washing. Here, also, the soap contributes 60 to 90 per cent and acetic acid 5 to 30 per cent of the B.O.D.

Choice of proper processing methods and chemicals can greatly reduce pollution. In scouring and finishing mills use of solvent scour methods which recover grease and suint could reduce the B.O.D. load as much as 50 per cent. Use of low-B.O.D. detergents in place of soap can lower the B.O.D. by 30 to 45 per cent. Use of ammonium sulfate in place of acetic acid can lower the B.O.D. by 2 to 15 per cent.

In finishing plants not scouring grease wool, replacement of soap may reduce the B.O.D. 60 to 90 per cent and replacement of acetic acid may reduce it 5 to 15 per cent. Additional substitutions for other high-B.O.D. process chemicals may reduce the over-all plant B.O.D. as much as 95 per cent and in many instances may eliminate the need for industrial waste treatment.

H. P. O.

Factors Affecting the Formation and Oxidation of Sulphides in a Polluted Estuary. BY A. B. WHEATLAND. *Jour. Hyg.*, **52**, 194 (1954).

Redox potential of muds at various depths with and without D.O. in the overlying water was investigated under laboratory conditions as a possible factor in sulfate reduction. The results showed that the presence or absence of D.O. in the water had no effect on redox potential of the mud at depths greater than 2 cm. below the mud-water interface and that conditions in lower layers are suitable for anaerobic bacteria whatever the oxygen content of the water.

In the Thames estuary sulfide is usually found when D.O. is absent. This might be either because D.O. inhibits sulfide production or sulfides produced are oxidized by D.O. An experiment was run to determine the minimum oxygen concentration to stop sulfide formation. Sewage, nutrient solution and mixed cultures of sulfate-reducing bacteria were aerated with nitrogen containing various percentages of air. With 2 per cent air (0.16 p.p.m. D.O.) in nitrogen gas, there was negligible sulfide production; with 1 per cent, sulfide production took place. Sulfides would not be formed, therefore, in waters containing any significant amount of D.O.; but they would be formed in mud

deposits in water containing D.O. and the oxidation in the water would be important.

Experiments with culture medium showed that below 15° C. sulfide production was greatly retarded; at 10° and 5° C. no sulfides were formed. However, with mixtures of mud and sea water sulfides were formed even at 5° and 10° C., but the quantity formed increased with temperature. It was concluded that the rate of sulfide formation in the estuary during the summer at 20° to 25° C. might be about three times as great as in the winter, other factors being equal. Whether the mud was kept in suspension or allowed to settle made no difference on sulfide formation when the water was anaerobic.

Experiments conducted with sea and estuary waters to which sulfide had been added and which had access to oxygen showed that sulfides were oxidized at the same rate in the sterile waters as in the non-sterile waters and therefore the oxidation was predominantly chemical. The rate of oxidation depended on the concentration of sulfide remaining to be oxidized. Oxidation was greater when the water contained Fe, an increase in the Fe content (by the addition of mud) resulting in increased oxidation. In estuary water containing mud, sulfide could be oxidized at very high rates (in some instances a half-life period of 1 hr.) if sufficient oxygen is present. The rate of entry of D.O. in estuary water is the factor controlling the rate of oxidation of sulfide. H. HEUKELEKIAN

Selected Bibliography of Publications Relating to Undesirable Effects upon Aquatic Life by Algicides, Insecticides and Weedicides. By W. M. INGRAM AND C. M. TARZWELL. USPHS Publ. No. 400 (Pub. Health Bibliography Series No. 13), U. S. Govt. Printing Off., Washington 25, D. C. 28 pp. Price, $0.15 (1954).

This booklet lists papers referring to the harmful effects of algicides, insecticides and weedicides on aquatic organisms other than those they were designed to control. The publication is not intended to discourage the use of such pesticides, but rather to enable those who use economic poisons to minimize or eliminate their damages to aquatic life by profiting from the experience of others as set forth in the papers cited.

Lists included make easy reference to papers dealing with specific chemicals and certain organisms. A section on bioassay references also is included. H. P. O.

BOOKS, REPORTS, AND PAMPHLETS

Community Planning and Development. *Bull. of Florida Eng. and Exper. Sta.*, Univ. of Florida, Gainesville, Fla., **8**, No. 5 (May, 1954).

Proceedings of the 7th Florida Municipal and Public Health Engineering Conference, held March 9–10, 1954.

Water Laws in Moslem Countries. Food and Agric. Org., United Nations. Columbia Univ. Press, 2960 Broadway, New York 27, N. Y. 202 pp. Price, $2.00 (1954).

Jersey City, N. J. Bond circular, Wright and Ramsay, Inc., New York, N. Y. (Aug. 24, 1954).

Prospectus on $22,000,000 in sewer revenue bonds based on sewer service charges ranging from $0.13 to $0.18 per 100 cu. ft. (Water rate is $0.12 per 100 cu. ft. to all users, with all services metered.)

Proceedings, Local Government Conference on Refuse Disposal Methods. University of Pittsburgh, Pittsburgh, Pa. 106 pp. (1954).

Proceedings, Sixth Pacific Northwest Industrial Waste Conference. University of Washington, Seattle, Wash. 61 pp. (1954).

Proceedings of the Third Annual Ohio Water Clinic. Special Report, Ohio State University Engineering Series. 144 pp. (Aug., 1954).

Includes the text of all papers and panel discussions presented at the clinic meeting (Feb. 11–12, 1954), which included the topics of stream sanitation, industrial pollution abatement, water conservation, and wastes recovery.

Circular Collectors

Types for every waste treatment problem

- DESIGNED FOR EFFICIENT LONG-TERM OPERATION
- ENGINEERED FOR USE IN CIRCULAR OR SQUARE TANKS
- SELECTION OF DRIVES TO MEET YOUR SPECIFICATIONS
- CLARIFLOW THICKENERS FOR FLUE DUST CLARIFICATION

TRACTOR DRIVE COLLECTOR

This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

WRITE FOR BULLETIN 9W65

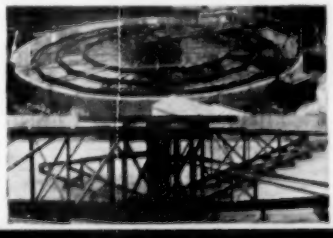
CLARIFLOW THICKENER

This unit utilizes the principles of fluid mechanics, so highly developed in Walker sedimentation units. It removes all settleable solids and remarkably clarifies the flow. All parts are sturdily built . . . designed for the "tough" jobs.

WRITE FOR BULLETIN 10169

PIER DRIVE COLLECTOR

The Pier Drive Collector is recommended where it is undesirable to operate a Tractor Drive . . . where the access bridge must be stationary, or the corners of square tanks must be scraped. Center drive mechanisms, ranging from 1/2 to 10 horsepower, are built for long life and heavy duty service. Worms are carburized and ground steel and precision meshed with hardened bronze worm wheels. The balls run in hardened, ground, renewable ball races.



WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.

Factory — Engineering Offices — Laboratories

Aurora, Illinois

Proceedings of Member Associations

GEORGIA WATER AND SEWAGE ASSOCIATION

The 1954 Annual Meeting of the Georgia Water and Sewage Association was held at the Georgia Institute of Technology, Atlanta, Ga., September 22–24, 1954, in conjunction with the Annual Georgia Water and Sewage School. The total registration reached a new high of 409.

The Federation's Arthur Sidney Bedell Award was presented to N. M. deJarnette.

Officers were elected as follows:

President: F. Lamb, La Grange.
1st Vice-President: W. W. Kiser, Rome.
2nd Vice-President: F. L. Futral, Newman.
Secretary-Treasurer: A. T. Storey, Atlanta.

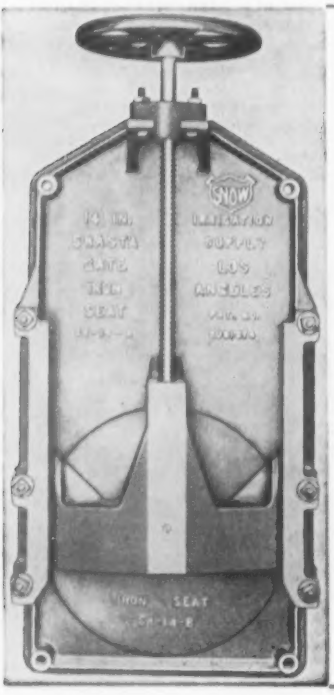
A. T. Story,
Secretary-Treasurer

PACIFIC NORTHWEST SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 21st Annual Meeting of the Pacific Northwest Sewage and Industrial Wastes Association was held in the Hotel Eugene, Eugene, Ore., on October 21–23, 1954.

Technical papers presented at the meeting included the following:

(*Continued on page 66a*)



SNOW GATES
for
SEWAGE TREATMENT PLANTS

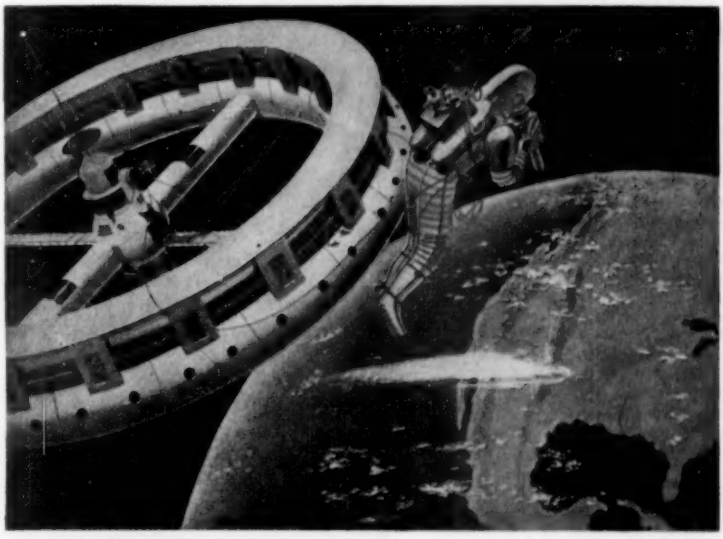
All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW GATES & VALVES
2437 East 24th Street Los Angeles 54, Calif.



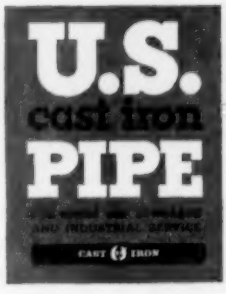
A SPACE STATION . . . a thousand miles high in the stratosphere slowly circling the globe . . . observers near its rim studying cloud formations and the earth's atmospheric conditions below . . . this may be our weather bureau of the future.

100 years from now...A MAN-MADE "MOON" MAY BE OUR WEATHER BUREAU

OUR WORLD of tomorrow will bring many changes. But in one vital aspect of American living, your great-grandchildren will continue to enjoy the same dependability and service you know today. *Cast iron pipe laid today will still carry water and gas to their homes.*

Today, over sixty American cities and towns are still served by cast iron water and gas mains laid 100 and more years ago. And modernized cast iron pipe, centrifugally cast, is even stronger, tougher, more durable.

U. S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.



United States Pipe and Foundry Company
General Office: Birmingham 2, Ala.

A wholly integrated producer from mines and blast furnaces to finished pipe.

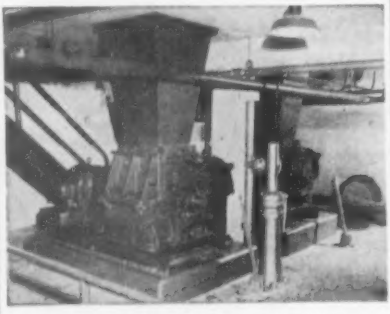
Since 1885

GRUENDLER

The Choice of Municipal Plants

25 Sewage Shredder Installations IN **1954**

Coney Island N. Y. Sewage Works
Kimball, Nebraska
Bedford, Virginia
Cleveland, Ohio, Hopkins Airport
Brooklyn, New York
White Bear Lake, Minnesota
St. Petersburg, Florida Airport
Houston, Texas
Albuquerque, New Mexico
Villa Park, Ill., Drainage Basin
Clear Lake, Iowa
Wichita, Kansas T.W.A.
Lexington, Virginia
Provo, Utah
Montgomery, Alabama
Camden, New Jersey
U. S. Army, Ft. Bliss, Texas
Monkato, Minneapolis
Charlestown, Mass. Pumping Sta.
New Bedford, Massachusetts
Waco, Texas
Henderson, Kentucky



Two Typical Gruendler Sewage Shredders

GRUENDLER
SEWAGE–GARBAGE–SHREDDERS

Disintegrate wastes, including rag stock, for continuous uninterrupted flow!

BULLETIN S.G. 10, mailed on request.

GRUENDLER
CRUSHER & PULVERIZER CO.

2915 North Market St., Dept. SIW, St. Louis 6, Mo.

"Composting Progress at Tacoma," by C. S. Seabrook, Sanitary Engineer, City of Tacoma, Wash.

"Automatic Controls in Sewage Treatment," by Lloyd K. Clark, Consulting Engineer, Salem, Ore.

"A Critical Appraisal of Sewage Operation and Design," by R. O. Sylvester, Associate Professor of Sanitary Engineering, University of Washington, Seattle, Wash.

"Financing, Design, Construction, and Operation of the Eugene Disposal Plant," by R. E. Roderick, H. F. Beistel, and William Newell.

"External Heat Exchangers," by J. W. Pratt, Process Engineers.

"Direct Heating by Steam Injection," by John W. Cunningham, Consulting Engineer, Portland, Ore.

"Digester Heating by Gas Engines," by A. L. McGee, Superintendent, Sewage Treatment Plant, Chehalis, Wash.

"Digester Heating by Heat Pump," by Mervin Minish, Engineer, Parker Hill and Ingman, Seattle, Wash.

"Cannery Waste Disposal by Irrigation," by G. H. Dunstan and J. V. Lunsford, Washington State College, Pullman, Wash.

Round table sessions on development and trends in sewage works, grit and screenings removal and disposal, sludge digestion and disposal, public relations, plant maintenance and safety, plant records, and the role of consulting engineers in industrial wastes problems, completed the meeting.

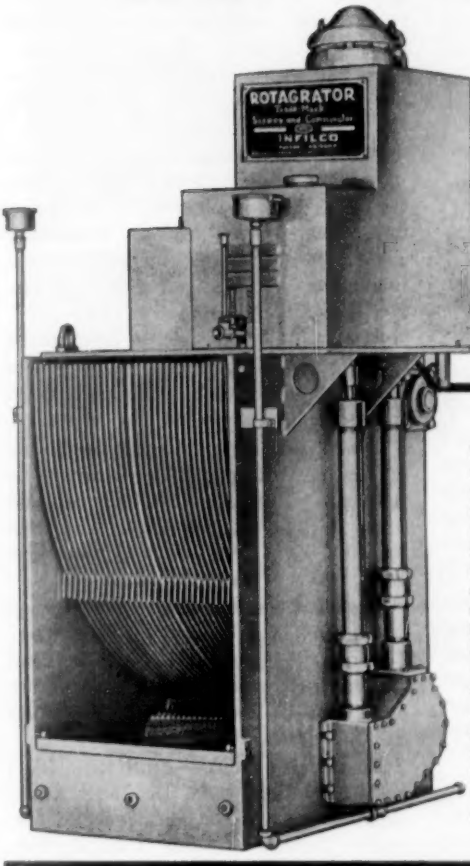
Inspection trips were made to various treatment plants in the vicinity.

Officers elected for 1955 were as follows:

President: F. Merryfield, Corvallis, Ore.
Vice-President: E. F. Eldridge, Olympia, Wash.
Secretary-Treasurer: W. W. Saxton, Olympia, Wash

W. W. Saxton,
Secretary-Treasurer

IT'S NEW!! IT'S REVOLUTIONARY!!



ROTAGRATOR
(Trade Mark)
screen and comminutor

Here is a unit that really screens and comminutes coarse sewage material without removal or rejection from the flow. Solids are held upstream until they are reduced to a size that permits passage downstream. Unpleasant and expensive manual removal methods, odors and other nuisances are eliminated when the "ROTAGRATOR" comminutor is installed. This equipment operates at a low head loss, and efficiently handles a wide variety of solids.
Straight line installation reduces initial costs. Low power requirements reduce operating costs.

The "ROTAGRATOR" screen and comminutor was developed for larger communities to complete INFILCO's extensive line of sewage and waste treatment equipment. For more information on the "ROTAGRATOR" comminutor and other INFILCO equipment, see your Consulting Engineer and write for literature.

Typical materials that have been successfully comminuted in the "ROTAGRATOR" comminutor include:

rags
cans
rubber products
glass
rope
wood

INFILCO

The one company offering engineered equipment for all types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

INFILCO INC.
921 South Campbell Ave., Tucson, Arizona
Field offices in principal cities in North America

Equipment and Supply Lines

Rotary Sludge Scraper—Rotary sludge scraper equipment is described in new releases giving engineering data.—Graver Water Conditioning Co., 216 W. 14th St., New York 11, N. Y.

pH Controllers—Bulletin Q1304 (36 pages) features details and engineering data on complete pH recording and controlling systems.—Bristol Co., Waterbury 20, Conn.

Automatic Titrimeter—New release describes the details and advantages of using a new automatic titration apparatus.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Temperature Regulators—A new comprehensive engineering bulletin (S–6) gives details on thermostatic temperature regulators.—Lawler Automatic Controls, Inc., 453 N. MacQuesten Parkway, Mt. Vernon, N. Y.

Telemeters—Technical Information 33–A–85a gives specifications and complete information on a new impulse-duration telemetering system for flow, pressure, level, temperature and other variables.—Foxboro Co., Foxboro, Mass.

Masonry Hole Cutter—New masonry hole cutting machine is portable, lightweight, high speed, cuts holes ½ in. to 10 in. in diameter through hard aggregate and steel reinforcement.—Molco Drilling Machines, Inc., Washington, D. C.

Package Plants—Package activated sludge plants for industry and communities up to 2,000 population equivalent are described in new Bulletin No. 22879.—Walker Process Equipment Inc., 840 N. Russell St., Aurora, Ill.

Controlled Volume Pumps—New 24-page Bulletin No. 1253 describes the use of controlled volume pumps in process instrumentation, both generally and in specific industry application. Also included are engineering data on the effect of fluid characteristics and piping on pump operation.—Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Plastic Coatings—Properties of plastic coatings and their application for metal products protection are given in several memo leaflets describing specific industrial uses to combat corrosion and abrasion.—Arbonite Corp., 900 N. Main St., Doylestown, Pa.

Measuring and Control Equipment—Bulletin 050 illustrates various types of control metering equipment, both of the primary and secondary types.

Pressure Filters—An extensive line of pressure filters and accessories for removal of suspended solids, oil and color is described in revised Bulletin No. 2225–B.—Permutit Co., 330 West 42nd St., New York 36, N. Y.

Packings and Gaskets—New 6-page folder PK–80A describes "Chempac" Teflon-treated asbestos packings and gaskets for chemical and process equipment.—Johns-Manville, 22 East 40th St., New York 16, N. Y.

Chemical Pumps—Bulletin 725.4 gives detailed data on centrifugal chemical pumps for abrasive and corrosive liquids.—Goulds Pumps, Inc., Dept. SI, Seneca Falls, N. Y.

Refractories—A series of booklets describes refractory products for various industries, including incineration and other uses.—Norton Co., Worcester 6, Mass.

Portable Pumps—Bulletin F–04 gives complete data on portable pumps for fire and other emergency uses.—Marlow Pumps, Ridgewood, N. J.

Hoists—A full line of air and electric hoists for handling bulk materials of all types is described in Bulletin 5300–A.—Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.

36" CONE VALVES

with clear opening

To supplement its hydroelectric power, TVA has built a series of steam plants on the Tennessee and Ohio rivers. These new units will furnish power required for Atomic Energy and other projects.

In this vital program, 52 Chapman Automatic Cone Valves were utilized for these plants . . . to act as check valves on the condenser water pumps. Each of these valves weighs approximately 11 tons.

Chapman designs and builds these valves in a range of sizes from 6" to 48" for check, throttling, pressure reduction and stop valve service. This is only one of many special Chapman valves. Remember, there's no problem in flow control that's too big or too tough for Chapman.

That's why it saves time and money to *check with Chapman first, every time.*

The **CHAPMAN VALVE**
Manufacturing Company
Indian Orchard, Mass.

DIRECTORY OF ENGINEERS

(Continued through page 75a)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING — VALUATIONS
REPORTS — LABORATORY
Suite 1509-18 121 S. Broad St. — PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick — Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building — Chicago

ANDERSON-NICHOLS & Company
Consulting Engineers
Water Supply, Distribution and Treatment, Industrial Waste Treatment, Sewage Collection and Disposal, Refuse Collection and Disposal, Drainage, Highways and Bridges.
Concord, N. H. — Boston 14 — Baltimore, Md.

JOHN J. BAFFA
Consulting Engineer
Sewerage & Sewage Treatment
Industrial Wastes Treatment
Design Plans & Specifications
Investigations & Rate Studies
75 West Street — New York 6, N. Y.

MICHAEL BAKER, JR., Inc.
The Baker Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER AND WOODMAN
Civil and Sanitary Engineers
Water Supplies — Water Treatment
Sewer Systems — Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 — Crystal Lake, Illinois

BLACK & VEATCH
Consulting Engineers
SEWAGE - WATER - ELECTRICITY - INDUSTRY
Reports, Design, Supervision of Construction
Investigations, Valuation and Rates
4706 Broadway — Kansas City 2, Missouri

W. H. & L. D. BETZ
Consulting Engineers
Industrial Waste
Industrial Water
Analysis — Design
Investigations — Operation
Gillingham & Worth Sts. — Philadelphia 24, Pa.

BOGERT AND CHILDS
Consulting Engineers
CLINTON L. BOGERT — FRED S. CHILDS
IVAN L. BOGERT — DONALD M. DITMARS
ROBERT A. LINCOLN — CHARLES A. MANGANARO
WILLIAM MARTIN
Water & Sewage Works — Refuse Disposal
Drainage — Flood Control
Highways and Bridges — Airfields
624 Madison Ave., New York 22, N. Y.

Take advantage of the services of these outstanding consultants!

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal—Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

BROWN AND BLAUVELT
Consulting Engineers
Water Supply — Airports
Sewer Systems — Highways
Sewage Disposal Plants — Industrial Buildings
Industrial Wastes Problems — Railroads
468 Fourth Avenue New York 16, N. Y.

BROWN AND CALDWELL
CIVIL AND CHEMICAL ENGINEERS
WATER · SEWAGE · INDUSTRIAL WASTE
CONSULTATION · DESIGN · OPERATION
CHEMICAL AND BACTERIOLOGICAL LABORATORIES
66 MINT STREET SAN FRANCISCO 3

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street New York 3, N. Y.

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Sewage and industrial wastes disposal
Investigations, reports, design, rates
Laboratories, Plant Supervision
2015 W. Fifth Ave. Columbus 12, Ohio

BURNS & McDONNELL
Consulting and Designing Engineers
Kansas City 2, Mo. P.O. Box 7088
Cleveland 14, Ohio 1404 E. 9th St.

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — WATER WORKS
Designs and Surveys — Roads and Streets
Planning — Airports
Bridges — Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants–Incineration–Gas Systems
Valuations–Rates–Management
Laboratory–City Planning
210 E. Park Way, Pittsburgh 12, Penna.

CHAS. W. COLE & SON
Engineers ~ Architects
Municipal *Industrial*
Commercial
220 W. LaSalle St., South Bend, Ind.
Phone 4-0127

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. Chicago 11, Ill.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

It pays to secure competent and experienced engineering advice!

Damon & Foster

Consulting Civil Engineers and Surveyors

Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision

Sharon Hill, Pennsylvania

FREDERICK H. DECHANT
ENGINEER

Chairman of the Board, Frederic R. Harris Inc.

Water Works, Industrial Wastes, Sewerage, Recovery Processes, Hydraulic Works, Gas Plants

Philadelphia: Fidelity Phila. Trust Bldg.
New York: 27 William St.

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways
Grade Separation—Bridges—Subways
Local Transportation

Investigations — Reports — Appraisals
Plans and Supervision of Construction

150 North Wacker Drive — Chicago 6
505 Colorado Bldg. — Washington 5

CONSULTING ENGINEERS!

If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .

Official Professional Journal of the Sewage and Industrial Wastes Field!

CATHODIC PROTECTION

Engineering—Surveys—Design—Installation

Electro Rust-Proofing Corp. (N.J.)
Belleville 9, New Jersey

FAY, SPOFFORD & THORNDIKE
ENGINEERS

JOHN AYER — RALPH W. HORNE
BION A. BOWMAN — WILLIAM L. HYLAND
CARROLL A. FARWELL — FRANK L. LINCOLN
HOWARD J. WILLIAMS

Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment
Airports—Bridges—Turnpikes
Port and Terminal Works—Industrial Bldgs.

BOSTON — NEW YORK

FINKBEINER, PETTIS & STROUT

CARLETON S. FINKBEINER — CHARLES E. PETTIS
HAROLD K. STROUT

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage, Sewage Treatment, Wastes Treatment
Valuations & Appraisals

518 Jefferson Avenue — Toledo 4, Ohio

FREESE, NICHOLS AND TURNER

Consulting Engineers

2111 C & I Life Building
Houston 2, Texas
CH-1624

FROMHERZ ENGINEERS

Structural - Civil - Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Industrial Waste Disposal
Investigations; Reports; Plans and Specifications; Supervision

816 Howard Avenue — New Orleans 12, La.

Your firm should be listed here

. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

EDWARD A. FULTON

Consulting Engineers

Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control

3209 Brown Road — Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS

Dams, Water Works, Sewage, Industrial Wastes & Garbage Disposal, Highways, Bridges & Airports, Traffic & Parking—Appraisals, Investigations & Reports.

HARRISBURG, PENNA.

Branch Offices: Pittsburgh, Pa. Philadelphia, Pa. Daytona Beach, Fla. Pleasantville, N. J. Chesapeake, W. Va.

Take advantage of the services of these outstanding consultants!

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports
New York Houston 607 Washington St. READING, PA. Washington Philadelphia

GLACE AND GLACE
Consulting Sanitary Engineers
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction and Supervision of Operation
1001 N. Front Street Harrisburg, Pa.

GREELEY & HANSEN
Engineers
Samuel A. Greeley Paul Hansen (1920–1944)
Paul E. Langdon Kenneth V. Hill
Thomas M. Niles Samuel M. Clarke
Water Supply, Water Purification
Flood Control, Drainage, Refuse Disposal
Sewerage, Sewage Treatment
220 S. State Street, Chicago 4

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

HASKINS, RIDDLE & SHARP
Consulting Engineers
Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction
Appraisals, Valuations, Rate Studies
1009 Baltimore Ave. Kansas City 5, Mo.

HAVENS AND EMERSON
W. L. Havens C. A. Emerson
A. A. Burger F. C. Tolles F. W. Jones
H. H. Moseley J. W. Avery F. S. Palocsay
E. S. Ordway
Consulting Engineers
Water, Sewerage, Garbage, Industrial Wastes, Valuations—Laboratories
Leader Bldg. Cleveland 14, O. Woolworth Bldg. New York 7, N. Y.

HAZEN AND SAWYER
ENGINEERS
Richard Hazen Alfred W. Sawyer
Municipal and Industrial Water Supply
Purification and Distribution
Sewage Works and Waste Disposal
Investigations, Design,
Supervision of Construction and Operation
110 East 42nd Street New York 17, N. Y.

HENNINGSON, DURHAM & RICHARDSON, INC.
Consulting Engineers since 1917 for more than 600 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage
Standard Oil Bldg. Omaha 2, Nebraska

HORNER & SHIFRIN
Consulting Engineers
W. W. Horner E. E. Bloss
H. Shifrin V. C. Lischer
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

JONES, HENRY & WILLIAMS
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. FT. LAUDERDALE, FLA.

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design
Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

It pays to secure competent and experienced engineering advice!

MORRIS KNOWLES Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. Pittsburgh 22, Pa.

KOEBIG AND KOEBIG
Consulting Engineers Since 1910
Investigations, Reports,
Designs and Appraisals
Sewerage & Sewage Treatment
Water Supply & Water Treatment
Municipal Engineering
Industrial Buildings
3142 Wilshire Blvd., Los Angeles 5, Calif.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester, 4, N. Y.

GEORGE B. MEBUS
Consulting Engineer
Water Supply Sewage Treatment
Industrial Waste Treatment
NORTHWESTERN NATIONAL BANK BUILDING
GLENSIDE, PA.

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airfields
Statler Building
Boston 16

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

PARSONS, BRINCKERHOFF HALL & MACDONALD
G. Gale Dixon, Associate
Wellington Donaldson, Staff Consultant
Water, Sewage, Drainage and Industrial Waste Problems.
Structures — Power — Transportation
51 Broadway New York 6, N.Y.

E. C. PATTEE
Consulting Chemical Engineer
Industrial Waste Disposal
Process Development, Surveys & Design
Provident Bank Bldg., Cincinnati 2, Ohio

PIATT AND DAVIS
WM. M. PIATT P. D. DAVIS
Consulting, Designing, and Supervising Engineers
Water Works, Sanitary Sewers, Water Purification
Sewage Treatment, Public Buildings, Streets
Power Plants, Electrical Distribution
Reports and Appraisals
One Eleven Corcoran St. Bldg. Durham, N. C.

MALCOLM PIRNIE ENGINEERS
Civil and Sanitary Engineers
Malcolm Pirnie Ernest W. Whitlock
Robert D. Mitchell Carl A. Arenander
Malcolm Pirnie, Jr.
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 West 43rd Street New York 36, N. Y.

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
36 De Grasse St. Paterson 1, N. J.

THOMAS M. RIDDICK
Consulting Engineers and Chemists
Municipal and Industrial Water Purification,
Sewage Treatment Plant Supervision,
Industrial Waste Treatment
Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. New York 55, N.Y.

Take advantage of the services of these outstanding consultants!

RIPPLE AND HOWE
Consulting Engineers
O. J. RIPPLE B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports
833-35 Twenty-Third St. Denver 5, Colorado

RUSSELL AND AXON
Consulting Engineers
Civil — Sanitary — Structural
Industrial — Electrical
Rate Investigations
408 Olive St., St. Louis 2, Mo.
Municipal Airport Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of Municipal Public Works & Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports
209 S. High St. Columbus 15, Ohio

HENRY W. TAYLOR
Consulting Engineer
Water Supply, Sewerage
Refuse Disposal, Incineration
Industrial Developments
151 W. Merrick Rd. Freeport, N.Y.

J. STEPHEN WATKINS
J. S. WATKINS G. R. WATKINS
CONSULTING ENGINEERS
Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.
251 East High Street Lexington, Kentucky
Branch Office
901 Hoffman Building Louisville, Kentucky

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

WESTCOTT & MAPES, Inc.
Engineers
VALUATIONS—STUDIES—REPORTS
DESIGN—SUPERVISION
Industrial Waste Problems
Utilities—Industrial Plants
Commercial Buildings—Institutions
Public Works
New Haven, Connecticut

WESTON & SAMPSON
Consulting Engineers
Water Supply Water Purification
Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

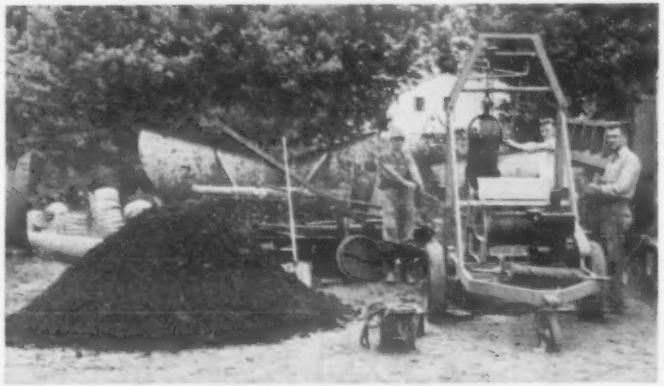
WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil — Sanitary — Structural
Mechanical — Electrical
Reports, Plans Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

It pays to secure competent and experienced engineering advice!

CUTTING SEWER MAINTENANCE COSTS WITH "Flexibles" AT LAPEER, MICHIGAN

Over 4 yards of sand just removed from the first 125 feet of trunk line in record time. No working at bottom of manhole; all deposits dumped at the street level. Just the start of an easy job that would have been tough *without* "Flexibles."

Sand, gravel, mud, rocks, roots, grease or slime–whatever your city's problems–"Flexibles" take them in stride, in all weather. For emergency cleaning or preventative maintenance, "Flexibles" are easier on the men–easier on the taxpayer. And there's a "Flexible" model for every requirement...budget or otherwise.



FREE DEMONSTRATION INVITED

Flexible SALES CORPORATION

3786 DURANGO AVE., LOS ANGELES 34, CALIF.

(Distributors in Principal Cities)

AMERICA'S LARGEST LINE OF PIPE CLEANING TOOLS AND EQUIPMENT

INDEX TO ADVERTISERS

	Page
Builders-Providence, Incorporated (B-I-F Industries, Inc.)	42a
Cast Iron Pipe Research Association	9th, 51a
Chain Belt Company	52a
Chapman Valve Manufacturing Company	60a
Chicago Pump Company	41a
Clow, James B., and Sons (Iron Valve)	57a
Combustion Engineering, Incorporated (Raymond Division)	36a
Dorr-Oliver Incorporated	65a
Fischer and Porter Company	54a
Flexible Sales Corporation	76a
Gruendler Crusher and Pulverizer Company	66a
Inertol Company, Incorporated	49a
Infilco Incorporated	67a
Link-Belt Company	55a
Morse Boulger Destructor Company	58a
Pacific Flush Tank Company	60a
Rockwell Manufacturing Company (Henderson Valve Division)	59a
Simplex Valve and Meter Company	48a
Stow Gates and Valves	64a
United States Pipe and Foundry Company	63a
Vapor Recovery Systems Company	52a
Walker Process Equipment, Incorporated	61a
Wallace and Tiernan Company, Incorporated	Back Cover
Yeomans Brothers Company	45a, 46a

DIRECTORY OF ENGINEERS, pp. 70a-78a

Albright & Friel, Inc.
Alvord, Burdick & Howson
Anderson-Nichols & Company
Bafle, John J.
Baker, Michael, Jr., Inc.
Baxter & Woodman
Betz, W. H. & L. B.
Black & Veatch
Eggert and Caldis
Howe, Albertson & Associates
Brown & Blauvelt
Brown & Caldwell
Buck, Seifert & Jost
Burgess & Niple
Burns & McDonnell
Camp, Dresser & McKee
Capitol Engineering Corp.
Chester Engineers, The
Coe, Chas. W. & Son
Coulter, Townsend & Associates
Damon & Foster
Dechant, Frederick H.
De Leuw, Cather & Company
Electro Rust-Proofing Corp. (St. J.)
Fay, Spofford & Thorndike
Finkbeiner, Pettis & Strout
Freese, Nichols & Turner
Frosshers Engineers
Fulton, Edward A.
Gannett, Fleming Corddry & Carpenter, Inc.
Gilbert Associates, Inc.
Glace and Glace
Greeley & Hansen
Hankins, Riddle & Sharp
Havens and Emerson
Hazen & Sawyer
Hennington, Durham & Richardson, Inc.
Horner & Shifrin
Jones, Henry & Williams
Kelz & Holroyd
Kennedy, Clyde C.
Knowles, Morris, Inc.
Koebig & Koebig
Lozier, Wm. S., Company
Mebus, George B.
Metcalf & Eddy
Nussbaumer, Clarke & Velzy, Inc.
Parsons, Brinckerhoff, Hall and Macdonald
Potter, E. C.
Pratt & Davis
Pirnie, Malcolm, Engineers
Powell, Lee T.
Riddick, Thomas M.
Ripple & Howe
Russell & Axon
Smith & Gillespie
Stanley Engineering Company
Stilson, Alden E., & Associates
Taylor, Henry W.
Watkins, J. Stephen
Westcott and Mapes, Inc.
Weston & Sampson
Whitman & Howard
Williams, Lequesne & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

LANCASTER PRESS, INC., LANCASTER, PA.

To Every Part Its Proper Place . . .

How well chlorination equipment does its job depends not only on proper design but on the selection of the right parts and materials for every specific purpose.

Every part in Wallace & Tiernan equipment is designed to meet a particular need. Mechanical diaphragms, first used by W&T in 1913, are still used where accurate control is the prime requisite. More recently developed puncture-proof water diaphragms provide visibility and accessibility of control parts when desired. Several types of meters, including the orifice and manometer, the rotameter (furnished in W&T equipment as early as 1917), and the pulsating types are all used for flow measurement, each employed where it best suits the purpose for which it is intended.

Since 1913, W&T Research has consistently sought out new designs, principles, and materials. Every new development is placed under rigid field tests to prove it can meet the exacting standards and practical limitations that dependable and economical chlorination demands.

When you depend on W&T equipment, you have the assurance that 40 years of experience in the chlorination field is being used to bring you the best in design, parts, and materials — selected and tested specifically to fit the need.

8-53-A

"Make Your First Choice Chlorination That Lasts"

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY